OVER 950 FACTS & ANSWERS INSIDE

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HOW IT WORKS

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STRIKES ON A PLANE

WHAT HAPPENS WHEN LIGHTNING HITS DURING FLIGHTS?

SOLVING THE MYSTERIES OF BLACK HOLES

HOW A TELESCOPE NETWORK THE SIZE OF EARTH WILL REVEAL THE UNKNOWN

10 INVENTIONS THAT WILL CHANGE THE WORLD

+

PIGS' TAILS
MIRAGES
SELF-DRIVING LORRIES
HISTORY OF JEANS
RADIATION
SUPERGLUE
CATACOMBS

MASTERS OF DISGUISE

HOW ANIMALS USE CLEVER CAMOUFLAGE TO KEEP HIDDEN

HOW TO WIN A DUEL

En garde! Master the art of defending your honour

ELECTRIC VS HYDROGEN

Which cars will win the race to replace petrol engines?

ROYAL RECORDS

Meet the monarchs who have made history

Future
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ISSUE 105

WELCOME

The magazine that feeds minds!

"Many animal species have developed some kind of mechanism to hide from their enemies, even at point-blank range..."

Masters of disguise, page 52

Meet the team...

Charlie G
Production Editor
Black holes are one of the universe's biggest mysteries. Venture into the world of these endless voids on page 14 (just don't step beyond the event horizon...)

Charlie E
Staff Writer
Moon geese, sewing and spacesuits — we speak to TV presenter Dallas Campbell about his inspiring new book, which explains how to leave our planet on page 12.

Scott
Staff Writer
As a pioneering physicist, Lise Meitner literally cracked the atom. She was an unsung hero in her field at the time, but you can discover her work now on page 50.

Duncan
Senior Art Editor
Now you see me, now you don't. How have some species in the animal kingdom developed the ability to hide in plain sight? Find out in our feature on page 52.

Laurie
Studio Designer
Who would have guessed that dropping an egg into water can show you whether it's fresh or has gone off? Flick to page 40 to discover more everyday life hacks.

FOLLOW US... How It Works magazine @HowItWorksmag

How do you image something invisible at the centre of a galaxy? By building an Earth-sized telescope of course. The Event Horizon Telescope is a global array that will help to create our first ever picture of a black hole. It is an exciting project that will hopefully reveal more about the strange behaviour of these mysterious cosmic singularities.

It's not just black holes that are tricky to spot though. Many animals and plants use clever camouflage techniques to disguise themselves. Check them out (if you can spot them!) in our environment feature.

Also this month, we take a look at some of the most important technologies under development today. From smart mosquito traps to help prevent the spread of malaria to 'vertical forest' buildings to help combat air pollution, there are plenty of exciting inventions to help improve the quality of life worldwide.

Enjoy the issue.

Jackie **Jackie Snowden**
Editor

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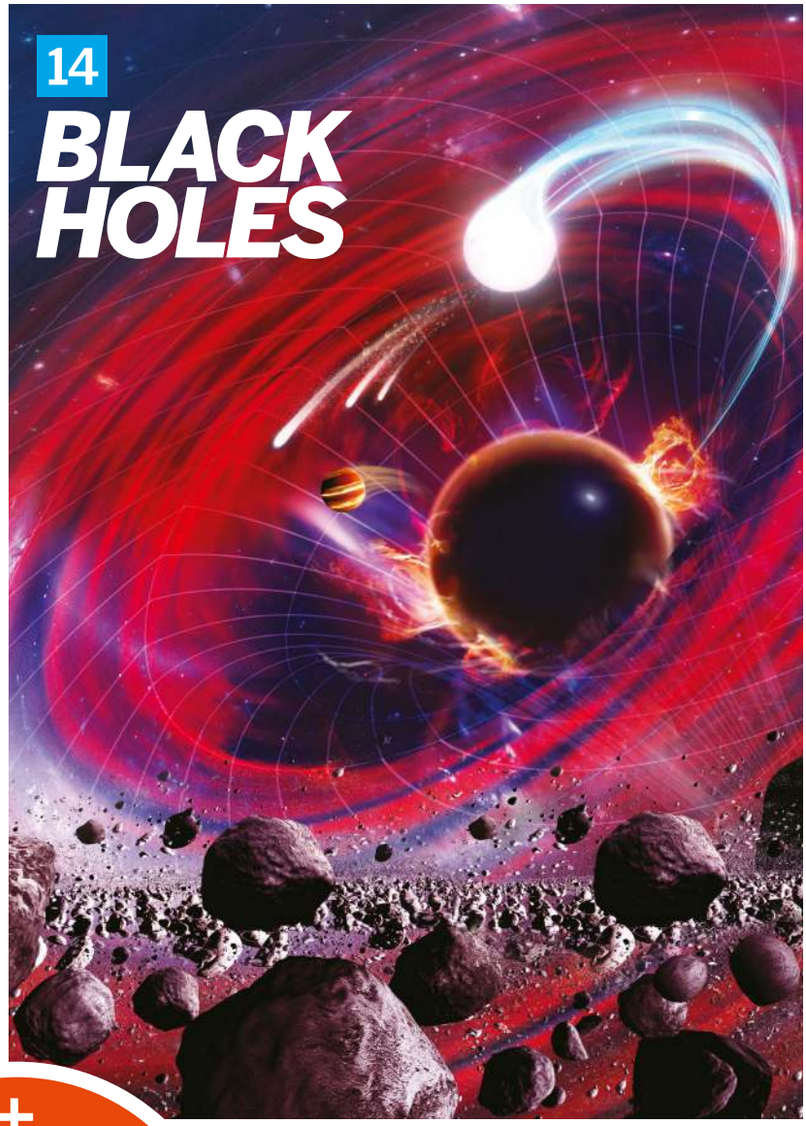


14 BLACK HOLES

+

HOW TO BUILD A ROCKET!
Prepare for lift-off with just paper and glue
PAGE 94

26 World-changing inventions

Meet the experts...

Jonny O'Callaghan
This month, Jonny takes us through some of the most inspiring and innovative inventions in development at the moment. Head to page 26 to find out more.

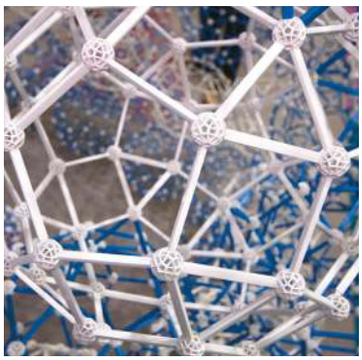
Jodie Tyley
Former **HIW** Editor Jodie is back to teach us how to win a duel when honour is at stake. She also unravels the surprising story of jeans and their journey from humble workwear to fashion staple.

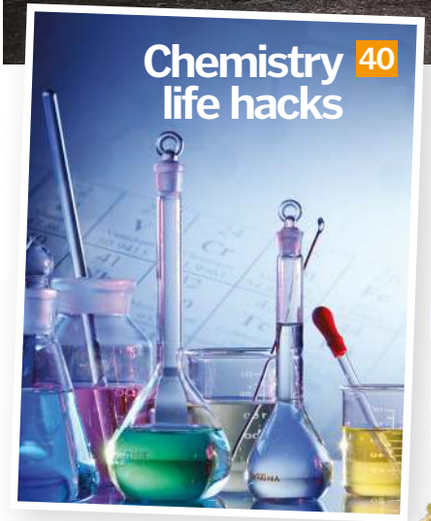
Katy Sheen
In this issue, Katy explains how the atmosphere can deceive our eyes to create floating illusions. She also investigates the mystery of why some pigs have curly tails.

Amy Grisdale
Regular contributor to our sister title **World of Animals**, Amy explains the fascinating ways in which animals use camouflage to their advantage in this month's environment feature.

Laura Mears
Laura brings us helpful tips for polishing silver and salvaging bitter coffee in our chemistry life hacks feature. She also reveals which royals are record holders in our history feature.

REGULARS





What we learned at New Scientist Live

Our highlights from the fantastic festival of scientific and technological ideas

For the third consecutive year, the annual New Scientist Live at ExCel London proved to be another wildly successful event. More than 30,000 people visited over four days to experience immersive exhibitions and hands-on activities inspired by the latest ideas in science and technology.

The show featured five engaging zones: Humans, Engineering, Technology, Earth, and Cosmos, hosting some of the biggest speakers in the industry, including Tim Peake, Chris Packham and Lucy Hawking. An important event to inspire the next generation of scientists, children dressed up in NASA spacesuits to meet their favourite astronauts and had the chance to get up close to unusual animals, such as stick insects and bizarre-looking naked mole rats!

The four-day exhibit explored some of humanity's biggest questions, such as how can we slow down aging and how will we get to Mars. Curious minds were invited to build their own microdrones, construct and race their own saltwater cars, or help scientists conduct research on their project about mosquitos and repellents. Pepper the robot made an appearance too, with guests able to interact with the humanoid social robot, the first such droid able to perceive human emotions, adapting his behaviour to the mood of the person interacting with him. Thrill-seekers were treated with a virtual reality rollercoaster, while visitors could also test their crime scene skills with a team of forensic scientists.

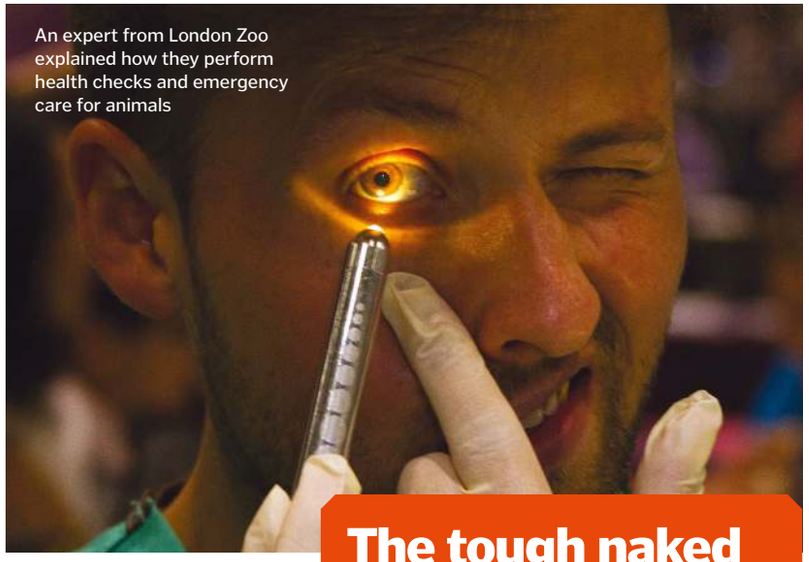
The event allowed enthusiasts from all over the country (and beyond) to meet the people shaping scientific innovation and discovery.

Al Worden commented, "Mars would be a chancey flight. I'm not sure what the odds are, but they wouldn't be as good as going to the Moon"

"When I am older I really want to become an astronaut and visit Mars. I have my own mission name, 'Mission Explore', because I want to explore the Red Planet." Chloe Mainstone — age nine

Tim Peake, Al Worden, and Helen Sharman

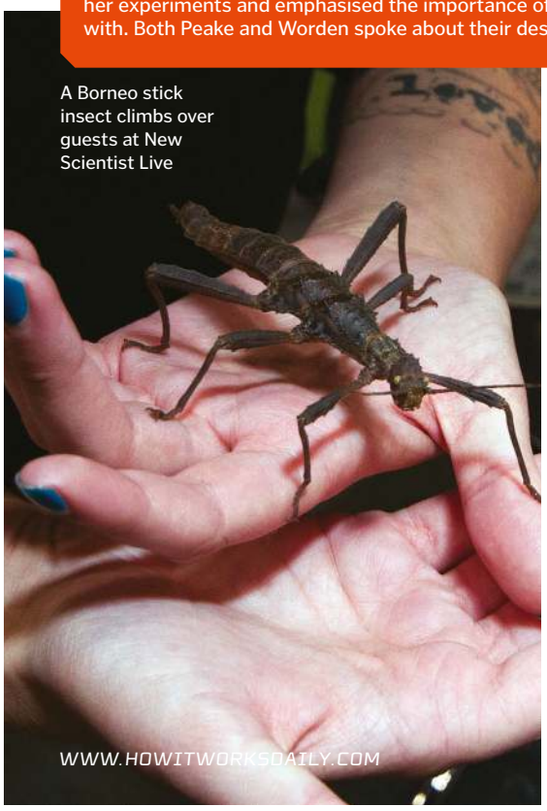
A stand-out moment at the event was the astronaut panel. Helen Sharman, the first Briton in space, was aboard the Soyuz TM-12 mission launched on 18 May, 1991. Tim Peake, the first British ESA astronaut, was the most experienced on the panel as a former International Space Station (ISS) crew member. Al Worden was a Command Module Pilot for Apollo 15, and is one of the few astronauts that have flown to the Moon. He spoke enthusiastically about seeing the Earth and Moon together for the first time in the first deep-space space walk. The team discussed their favourite moments of their missions: Sharman remembered fondly the feeling of weightlessness, her experiments and emphasised the importance of the team you go with. Both Peake and Worden spoke about their desire to go to Mars.



An expert from London Zoo explained how they perform health checks and emergency care for animals

The tough naked mole rats and how they survive

Our team caught up with Chris Faulkes, director of the Science and Engineering Foundation Programme at Queen Mary University of London. As a mammalian evolutionary biologist, Dr Faulkes' research focuses on the evolution and maintenance of social and reproductive behaviour of the naked mole rat. This fascinating animal lives underground, can survive 18 minutes without oxygen and is essentially cold blooded. Incredibly, they seem to be almost totally resistant to cancer! Studying them may hold the key to a lot of advancements in medicine.

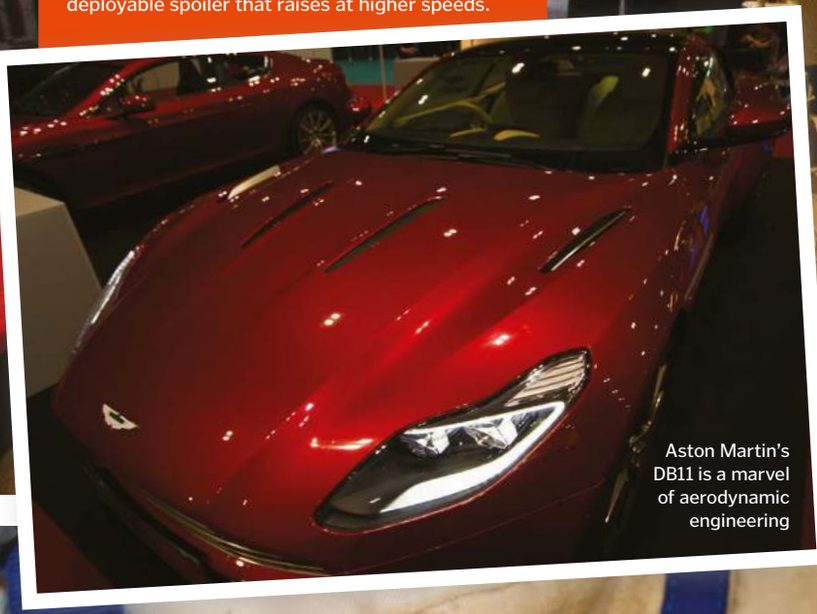


A Borneo stick insect climbs over guests at New Scientist Live

We couldn't work out if we found these guys cute or ugly? Or maybe a bit of both?

The amazing aerodynamics of the new Aston Martin DB11

Aston Martin's new DB11 features the largest aluminium clamshell bonnet made from a single sheet of metal, giving it both a beautiful and aerodynamic quality. The car is designed to generate downforce without a spoiler. The air is directed to an opening at the DB11's C-pillar, where it is then channelled into ducts within the bodywork. That air exits out of a tiny opening on the rear decklid, pressing the rear wheels into the surface like a spoiler would. Any excess air that channels over the roof is harnessed by a deployable spoiler that raises at higher speeds.

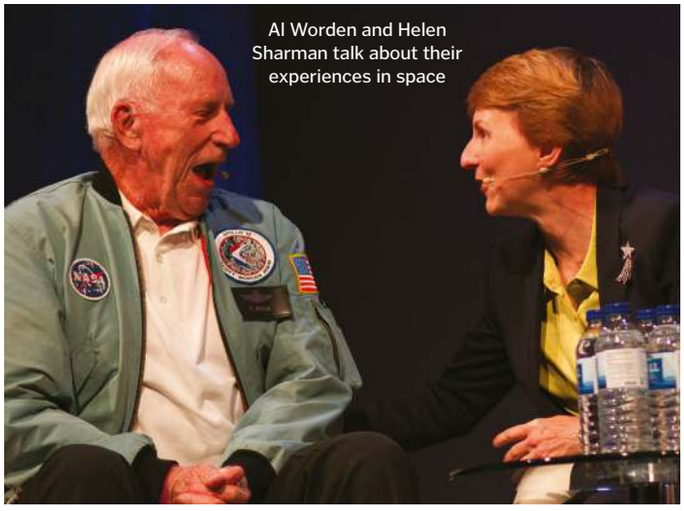


Aston Martin's DB11 is a marvel of aerodynamic engineering

Exhibitions meant that everyone was able to get up close to amazing objects — like this real spacesuit!

The London School of Health and Hygiene's mosquito project

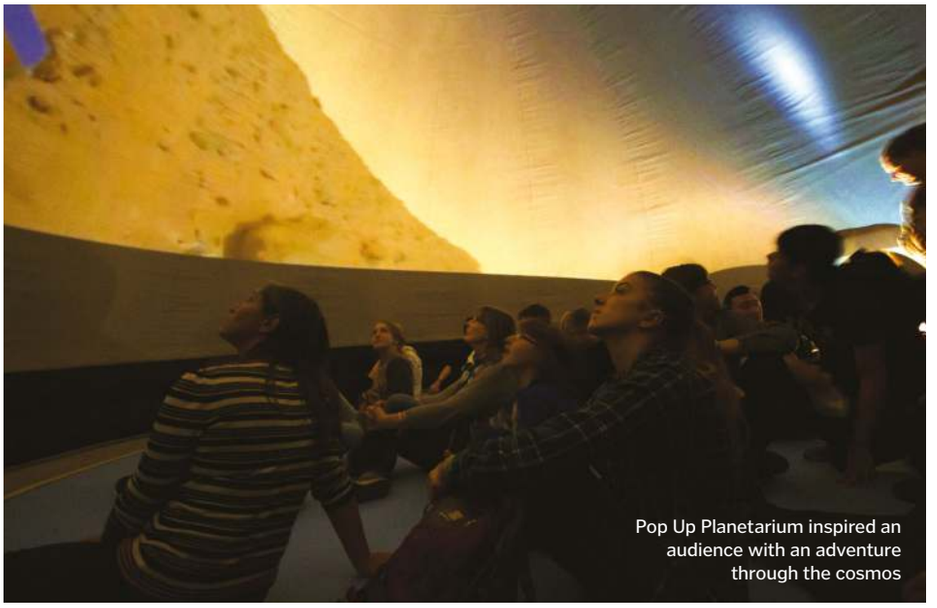
The London School of Health and Hygiene used a box made from a fine mesh cotton to hold tens of mosquitoes. They asked visitors to place their arm on the top of the box, so that the mosquitoes could fly towards their skin but were unable to bite. The researchers could then count the number of the insects that were attracted to each person. This data is being used as part of the research and development of mosquito repellents. It is estimated that more than 1 million people every year are killed by diseases carried by mosquitoes, the majority of which are due to the malaria parasite.



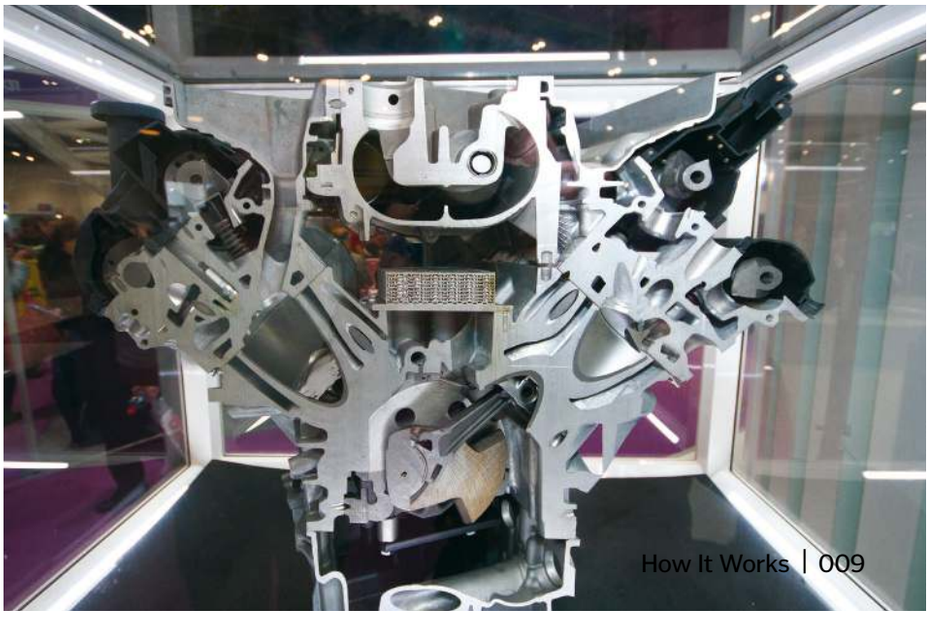
Al Worden and Helen Sharman talk about their experiences in space

Displays throughout the exhibition centre blended science and art

Plenty of interactive stands enabled visitors to immerse themselves in different scientific fields

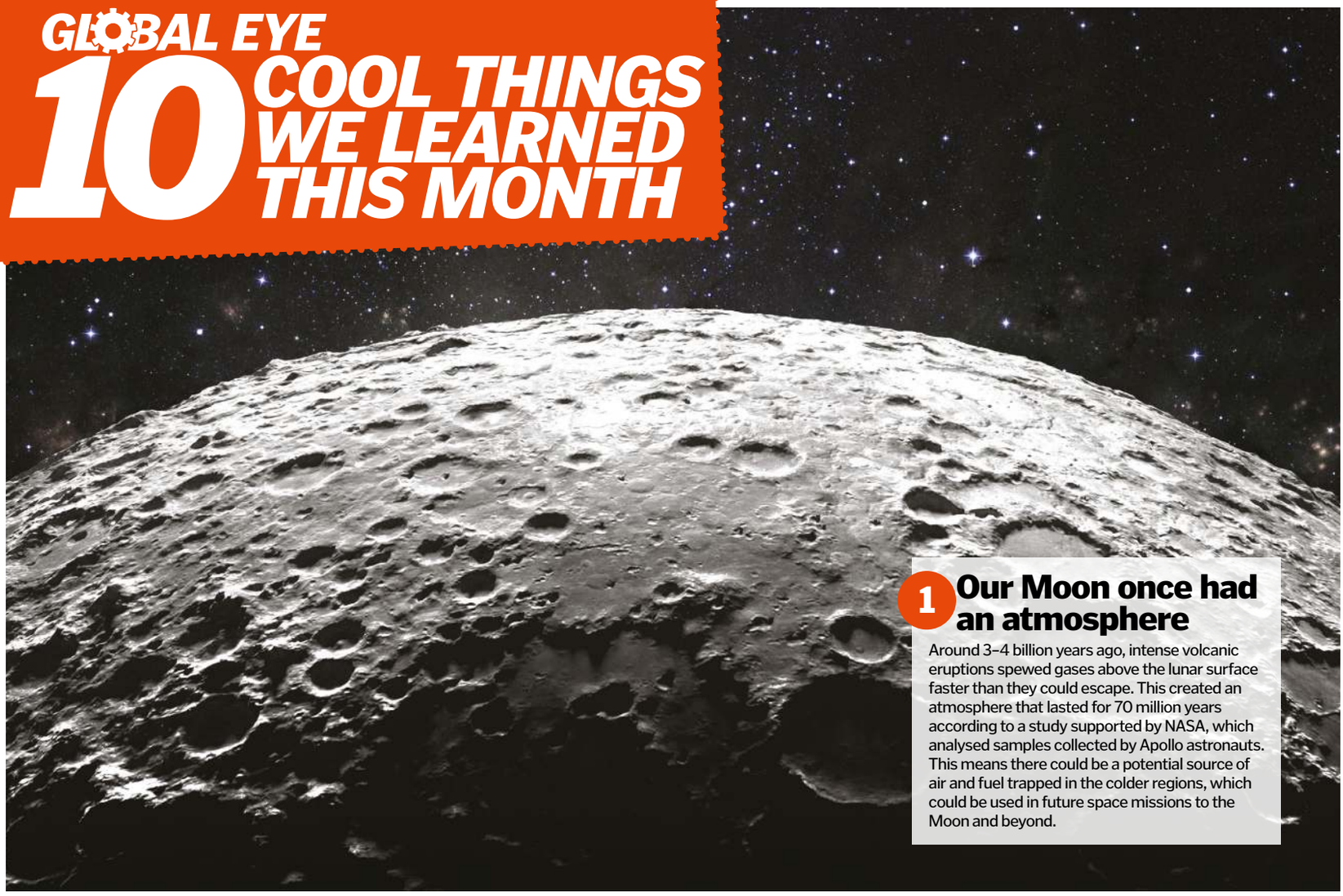


Pop Up Planetarium inspired an audience with an adventure through the cosmos



GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH

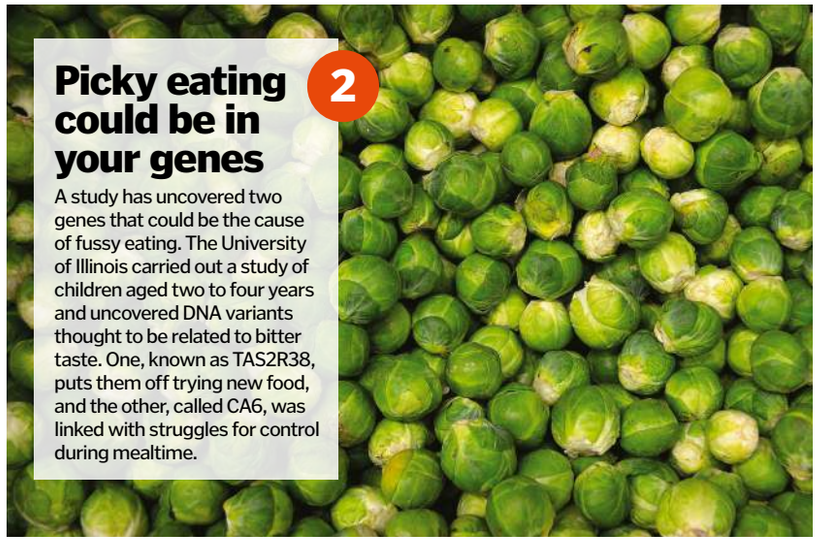


1 Our Moon once had an atmosphere

Around 3–4 billion years ago, intense volcanic eruptions spewed gases above the lunar surface faster than they could escape. This created an atmosphere that lasted for 70 million years according to a study supported by NASA, which analysed samples collected by Apollo astronauts. This means there could be a potential source of air and fuel trapped in the colder regions, which could be used in future space missions to the Moon and beyond.

3 Intelligent bandages can heal your body

A new 'smart' bandage is capable of dispensing multiple medications when triggered by a mobile device. Developed by researchers from the University of Nebraska-Lincoln, Harvard Medical School and MIT, the bandage consists of fibres coated in a gel that house anything from antibiotics to painkillers. When a small amount of voltage is applied, the fibre and its gel heat up, releasing the drugs. Further testing is needed, but it's hoped the bandage will eventually heal chronic wounds and battlefield injuries.

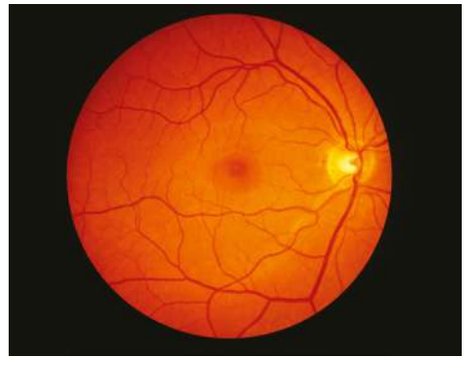


2 Picky eating could be in your genes

A study has uncovered two genes that could be the cause of fussy eating. The University of Illinois carried out a study of children aged two to four years and uncovered DNA variants thought to be related to bitter taste. One, known as TAS2R38, puts them off trying new food, and the other, called CA6, was linked with struggles for control during mealtime.

4 Gene therapy could reverse blindness

One of the most common forms of blindness in young people could be partially cured using gene therapy. By reprogramming the cells at the back of the eye to become light sensitive, researchers were able to give mice with retinitis pigmentosa a degree of vision. The team at the University of Oxford say the next step is to begin clinical trials.



Neanderthals still affect your health 5

We have our ancient human cousins to blame for health concerns such as blood cholesterol levels and arthritis. This follows a genetic study of the bones from a 52,000-year-old female Neanderthal found in Croatia. Another study showed that modern Europeans have twice as much DNA from Neanderthals than previously thought. These links stem from migrating *Homo sapiens* interbreeding with our ancient *Homo neanderthalensis* relatives in Europe 100,000 years ago.

Elon Musk plans to colonise Mars by 2024 6

The ambitious founder of SpaceX has announced plans for a new spacecraft destined for Mars. By putting all of the company's resources into the new rocket, Musk hopes to have the first launch by 2022 and send the first humans by 2024.

The remains of Santa may have been found 7

Archaeologists believe they have uncovered the final resting place of Saint Nicholas, better known as Santa Claus. They say scans of Turkey's Myra St Nicholas Church show a hidden tomb underneath the floor, but only an excavation will reveal the truth.

© Pixabay, Getty, NASA

We're one step closer to flying taxis 8

Airbus Helicopters have successfully completed testing its CityAirbus — an autonomous flying taxi that's powered entirely by batteries. The company is preparing for its first flight at the end of 2018, before official lift-off in 2023. CityAirbus will be designed to carry up to four passengers along fixed routes, soaring across the sky at a top speed of 120 kilometres per hour.

How giraffes stay cool 9

It's well-known that giraffes evolved long necks to reach high-up food, but there could be another possible explanation: to keep cool. Scientists argue that if a giraffe faces the Sun — as they have been seen to do during the day — their necks cast most of their body in shadow. This gives them a crucial advantage in hot habitats.

Barn owls never lose their hearing 10

Unlike mammals, birds are able to regenerate cells in their inner ears so they suffer minimal hearing loss as they get older. However, after testing the hearing ability of young and elderly barn owls of up to 23 years old, scientists found no notable difference at all. It's hoped that by understanding how this works we may be able to create treatments for humans.

INTERVIEW

Dallas Campbell

HIW's Charlie Evans speaks to broadcaster Dallas Campbell about his new book and his passion for space exploration

As a presenter on programmes such as *The Gadget Show*, *Horizon*, *Stargazing Live* and *Bang Goes the Theory*, Dallas Campbell's career has taken him all over the world. Along the way he has abseiled off the world's tallest building, dived through the sewers of Mexico City and witnessed Tim Peake's launch to the International Space Station. His new book, *Ad Astra: An Illustrated Guide to Leaving the Planet*, explains all you need to know about the trials and trivia of life off-Earth.

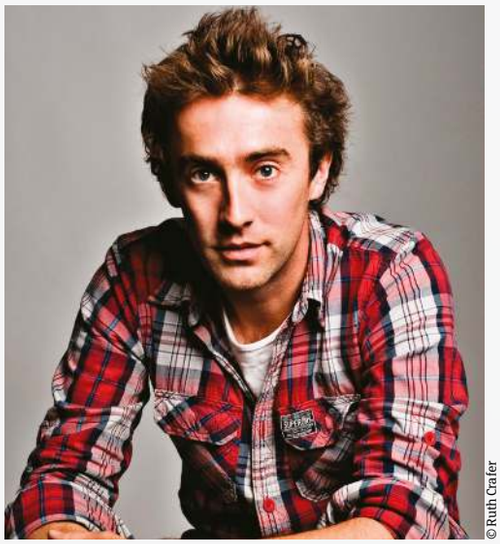
Your book takes a unique approach, what made you want to write it in this style?
I didn't want to just write the bumper book of space facts. There are so many books like that and I actually wanted to do something completely different and make something more complete, more with an arch, with things set up in Act 1 that maybe reappear in Act 3.

Is that your screenwriting background?
A little bit. For me writing isn't just noting facts down on a bit of paper. I knew what I roughly wanted to do: I had a rough structure with the concept of doing a guide book, and go from there.

It's visually spectacular. How did you decide on the imagery?
Sourcing pictures was the toughest thing. I'd stumble across pictures on the internet and try to find who owned them - it was a bit of work. It wasn't just 'Let's find some pictures', I wanted the pictures to jump out. It's curated.

How long did this take you to write?
It was exactly a year from 'I'm going to write a book' to today, so the actual writing was probably seven months, and there is a heck of a lot of research. There are things I already knew, but for the stuff I didn't know, for each subject there is libraries worth of information about that thing. You have to know everything to be able to distil it down into a couple of pages.

How did you distil it down?
I've been filming a lot this year, two big series that have taken me around the world, and I've been travelling a lot, so it's been hard to keep


© Ruth Crafer

track of a lot of information. The best source for me, the most satisfying source, was the British Interplanetary Society Library. It's behind Vauxhall station, this building with big letters on the wall that say British Interplanetary Society. I've known about it for years and I always thought that it was some kind of cult! But inside they have thousands and thousands of books about the whole history of space travel... on every conceivable subject, flight logs for every Apollo mission, photographs, it's absolutely jam packed. Actually writing was quite hard, because I was so distracted by new information. My goal was to take that whole library, squash it and put it in a single volume.

You include very practical issues that I never considered would be a problem.
That's the thing — I like the practical stuff, I like the niche, weird, practical side. I have got a whole section on the flag that they stuck on the Moon and how they made it and the engineering behind it, and the fact the flag cost $5.50 from Sears. To me this is interesting, the details — this is stuff people genuinely don't know about. All of these stories people have written about before — I'm not doing anything particularly new, but packaging them all together in one place I think is really nice.

The questions throughout the book, like 'Can we take a dog to space?' are almost childlike, yet it works really well.
There is so much to do with leaving the planet, it's not just about being an astronaut. Quite often there is bureaucracy, like do you need a passport? No is the answer.

What made you decide to write it this way?
Science writing tends to be 'this is science' and then separately there is literature, and I wanted to do something really creative, a bit different and a little more thoughtful. For me science is about stories. It's the same for television. Why do I want to write about space? It's because there is a good story, and good people, and within the story are little sub-stories which are fascinating. And science is just how we explore the world and space is just a bit more than that — but it's not much more than that.

In particular we really enjoyed the story about the women who made the Apollo space suits.
The most famous photograph ever taken off Earth, Buzz Aldrin standing on the Moon, which is certainly the most famous photo of the 20th century, but when you look at it — which nobody realizes and which really frustrates me — you're not looking at Buzz Aldrin, you're looking at an engineered object, that space suit. It's the International Latex Corporation, A7L spacesuit. So I wanted to champion the suit and the women who stitched them. They were from Delaware, and before that they had been stitching suitcases and garments and boxing gloves. They were just highly skilled individuals and that's a really nice thing to talk about. Sewing is this ancient craft we have been doing since the Stone Age and here we are employing it to build a space suit.

"You don't have to play the piano to like listening to music, yet somehow science has its own special rules. It's ridiculous"

Do you have a favourite story in there?
I like the integrated space plan, which was quite an early infographic. In 1989 a space engineer called Ron Jones created this infographic listing what we need to do to become an interplanetary species. So he charted all the things that we would need — things that needed to happen, manned vehicles and so on — in this incredible diagram. That's my favourite at the moment. I also really love the interviews. Partly from being bored of my own voice, I'd think 'I need someone else to tell me this', so I would bring in people like Beth Healy who lives in Antarctica for months on end and analogues space missions in complete isolation in -80 degrees in the dark, and the artist who bred geese as an art project to reflect the Moon geese from the 1600s — I think that is a really interesting story.

Moon geese?
There was a book called *L'Homme dans la Lune* (The Man on the Moon) in the 1600s, whereby they imagined these special geese called ganzer that would migrate from the Earth to the Moon, and if you could catch them somehow and tie yourself to them off you would go to the Moon. An artist decided to breed geese and imprinted them and named them all after astronauts — Neil, Svetlana, Gonzalez — she had this Moon goose colony and did this incredible series of photographs and little films, and I just loved it.

Did you always want to be a science communicator?
I always struggle with the notion science communicator. What does that mean? You don't say history communicator, or art, music — why is science different? You say science and they think of it as a subject. I don't, it's just telling stories. There is no distinction. I'm just interested in things, interested in nature, how the world works. I suppose the area that I am most known for is human geography, things like humans and planets and where they meet — transport, energy and cities — those sorts of areas which fascinate me, of which space is part of that. It was not a case of 'I'm now going to do science'.
My problem with the term 'science communicator' is it automatically assumes — let us communicate to those who don't understand the world of science. If you want science to truly be part of culture, then stop calling it science communication. You don't have to play the piano to like listening to music, yet somehow science has it's own special rules, which is ridiculous.

Like you said, people find it inaccessible.
I think it's because there is an assumption that when we talk about science one has to be a scientist. If you want to be a musician, for example, you need to learn how to play an instrument, or read music, but that doesn't exclude those who want to listen to music or enjoy talking about music. It's the same with science. We need science because it makes the world go around, but within science there is that natural story and that natural curiosity about how things work, which is why good science writing should be as respected as any other kind of writing. It takes you places, like any kind of writing, it's poetic, and there is wonder and beauty, and visually it's amazing. You read the works of great science writers, people like Carl Sagan and Richard Dawkins — who I think is a great science writer — and you are transported as if you were reading any other kind of book.

Do you think there may be a stereotype of science being elitist?
I used to do a TV show called *Bang Goes the Theory,* which is like this family science show. We had such a good time because we were covering all different areas of science and we were talking to the general public and it's not about being scientifically literate, it's about being interested. It's just this idea that science is somehow just the thing you did at school. When we talk about English or music or art, you don't see it as 'that thing you did at school'. You don't say to someone 'Let's go to a concert' and they reply 'I hate music, I was really bad at it at school'. Nobody says that, yet science is [described in that way]. I'm trying to break down that wall and get rid of all of that and trying to just normalise science. I'm trying to give people permission to enjoy it and not question it and not go 'Oh, I was rubbish at science at school'. In the book all of the stories about the human experiences and the trivia really help.

What advice do you have for kids who really want to get into space?
Don't try to be an astronaut — it is so unlikely. The last European group of astronauts was picked in 2009; they're not choosing astronauts all the time. If you dedicate your life to being an astronaut you're taking your eyes off the prize. The prize is to find something, what you love in life. I didn't set out to be a TV presenter; I study things, there are things I am interested in, and as a result I get to talk about them on TV. The TV thing is a by-product of being interested in the world. It's the same for being an astronaut. Go to university, go do subjects you love, learn to fly a plane, learn to scuba dive, explore the world about you. Don't think of astronaut as the end goal. Take Tim Peake for example, he didn't set out trying to be an astronaut. He went into the military and he has a love of flying and become a test pilot, and he enjoys the outdoors and camping — he just followed what he loved.

If given the chance to go to space tomorrow would you go?
How long do I have to go for?

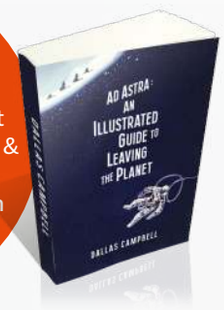
It's a one-way mission to Mars, they haven't planned a return yet.
No.

Okay, it's a two-way mission to Mars, but they don't know how long it will take.
No.

Alright, it's only 18 months.
No. Keep going.

In what circumstances would you go? I know there is a yes somewhere.
There is a yes. What makes a good astronaut… it's not just about being brilliant academically, it's about being a rounded individual. It's what happens when something goes wrong, because when you're in space nobody is going to come and rescue you, you have to deal with it. How you handle those situations is what makes an astronaut. 99 per cent of the time it will be fine, but you've got to prepare for that one per cent when it's not fine. And I'll be honest, I would cry, and I would scream, I'd probably have a hissy fit, and I am a hot head — it would be a catastrophe. So, for those reasons, I'm out. What I would like to do is a trip to the Moon, two days there, two days back. I'd like to go to the Apollo landing site. Hearing stories from the Apollo astronauts about the Moon, I think it's close enough that I'm not going to freak out, and you get the whole space experience: the weightlessness, getting to see Earth, getting to stand on another world.

Dallas' book *Ad Astra: An Illustrated Guide to Leaving the Planet* is out now, published by Simon & Schuster UK.
Check out our review on page 88.



Read the interview in full on our website

DETECTING THE INVISIBLE

Discover the mysterious world of black holes and the projects trying to capture them

Black holes are some of the most impressive and strangest astronomical oddities in existence. But, complex as they are, it was Albert Einstein who first predicted their presence back in 1916 with his theory of General Relativity. However, it wasn't until 1967 that astronomer John Wheeler coined the name 'black holes', a rather precise moniker given that not even light can escape one.

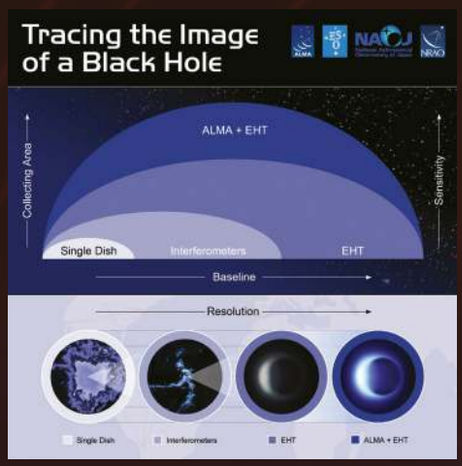
GALACTIC GIANTS

Born from the death of a star, stellar black holes are created by the collapsing of a star's mass and are the smallest form of black hole. Just as our Sun does, stars convert hydrogen into helium during nuclear fission at their core. The radiation caused by this reaction pushes against the star's gravitational forces, which push inwards. As long as there is a balance between the radiation and gravity, the star will remain as it is. However, as that radiation reduces over time, the fight against gravity also decreases. Eventually the gravity of the star forces its mass to fold in on itself, creating a stellar black hole, the resulting singularity around 30 or more times the mass of our Sun. Though stellar black holes are pretty big, there are others that make them look tiny.

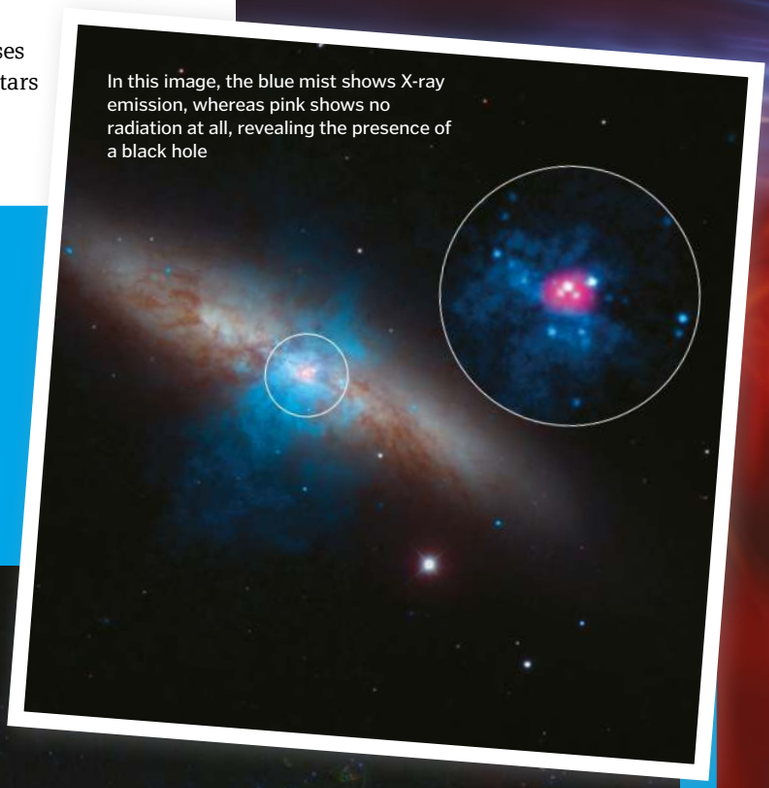
At the heart of galaxies are supermassive black holes. With the mass of more than 1 million Suns, these black holes are true galactic giants. While their origins are unclear, some suggest they are the result of the collapse of massive clouds of gas during the formation of the galaxy.

What is particularly interesting about supermassive black holes, and something scientist are keen to study, is its event horizon. The point at which nothing can escape the gravitation pull of a black hole, this border casts a 'shadow' over the black hole. For example, using a pen, draw a circle on a piece of paper. How do you see the circle on the page? The ink is revealing a circle, the same way as the event horizon reveals a black hole. At this point of descending infinite gravity, time itself is effected by the black hole's gravity. Black holes, however, don't act like a vacuum cleaner sucking up stardust but more a deep well into which objects irretrievably fall.

Currently, the existence of a black hole as we know it is theoretical. The reason we know these masses exist is because of the way stars and light act when one is nearby. Monitoring stars' positions in the universe,



Combining forces, EHT and ALMA have created an Earth-sized radio telescope

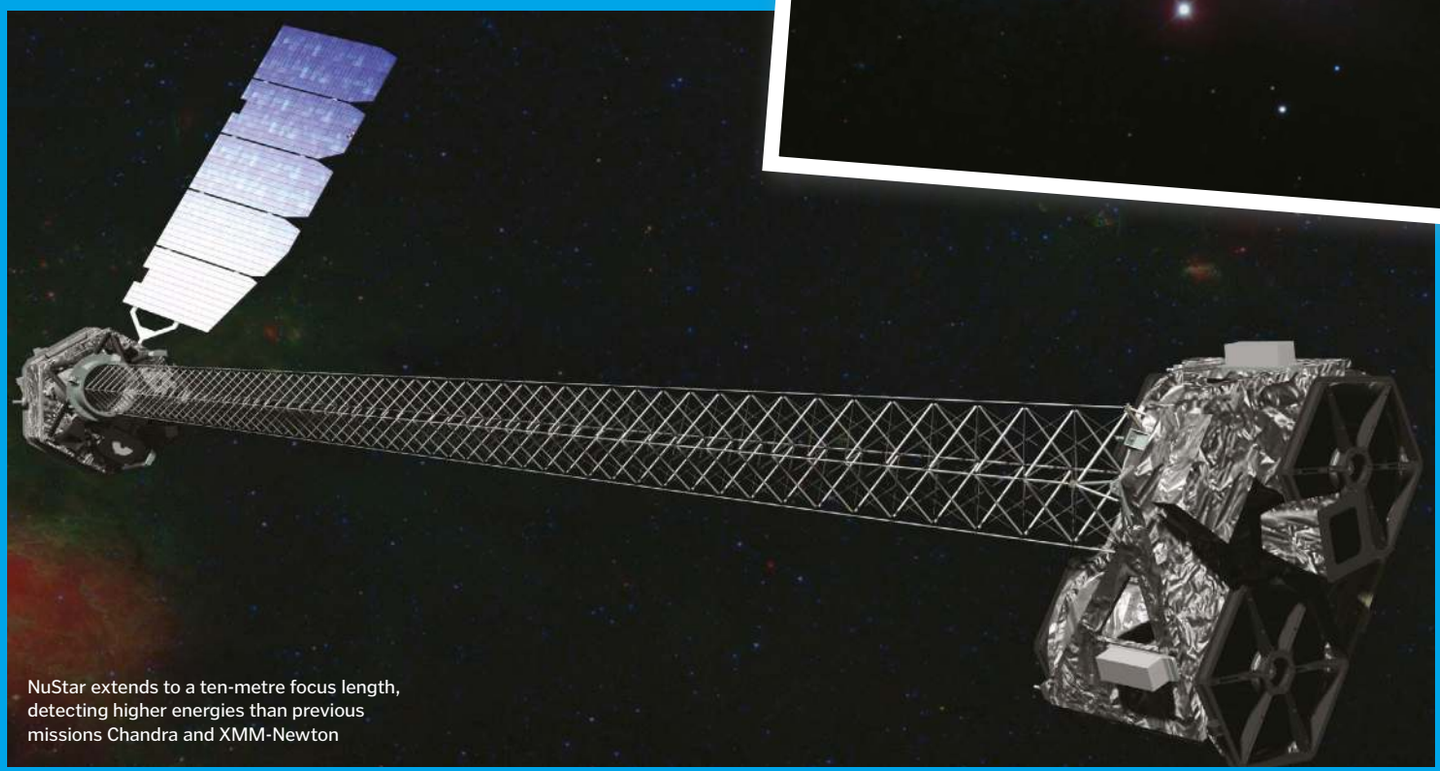


In this image, the blue mist shows X-ray emission, whereas pink shows no radiation at all, revealing the presence of a black hole

A SPY IN THE SKY

The Event Horizon project isn't the first attempt to form some sort of image of a black hole. Launched in 2012, the NuStar Telescope was the first telescope sent into space with the ability to focus on high-energy X-rays. This enabled researchers to identify the presence of a black hole but not capture an image of one. By detecting high-energy X-rays, NuStar can paint a picture of the location of a black hole and show the level of radiation coming from it.

The telescope has helped us understand merging galaxies, the structure of black holes and the results of their destructive force. Data collected has helped to form an image of key points in the life of a black hole, from its birth by a dying star to its devouring of a buffet of mass forming an energetic quasar. Five years on, the telescope is still spying on the universe and producing some extraordinary visuals.

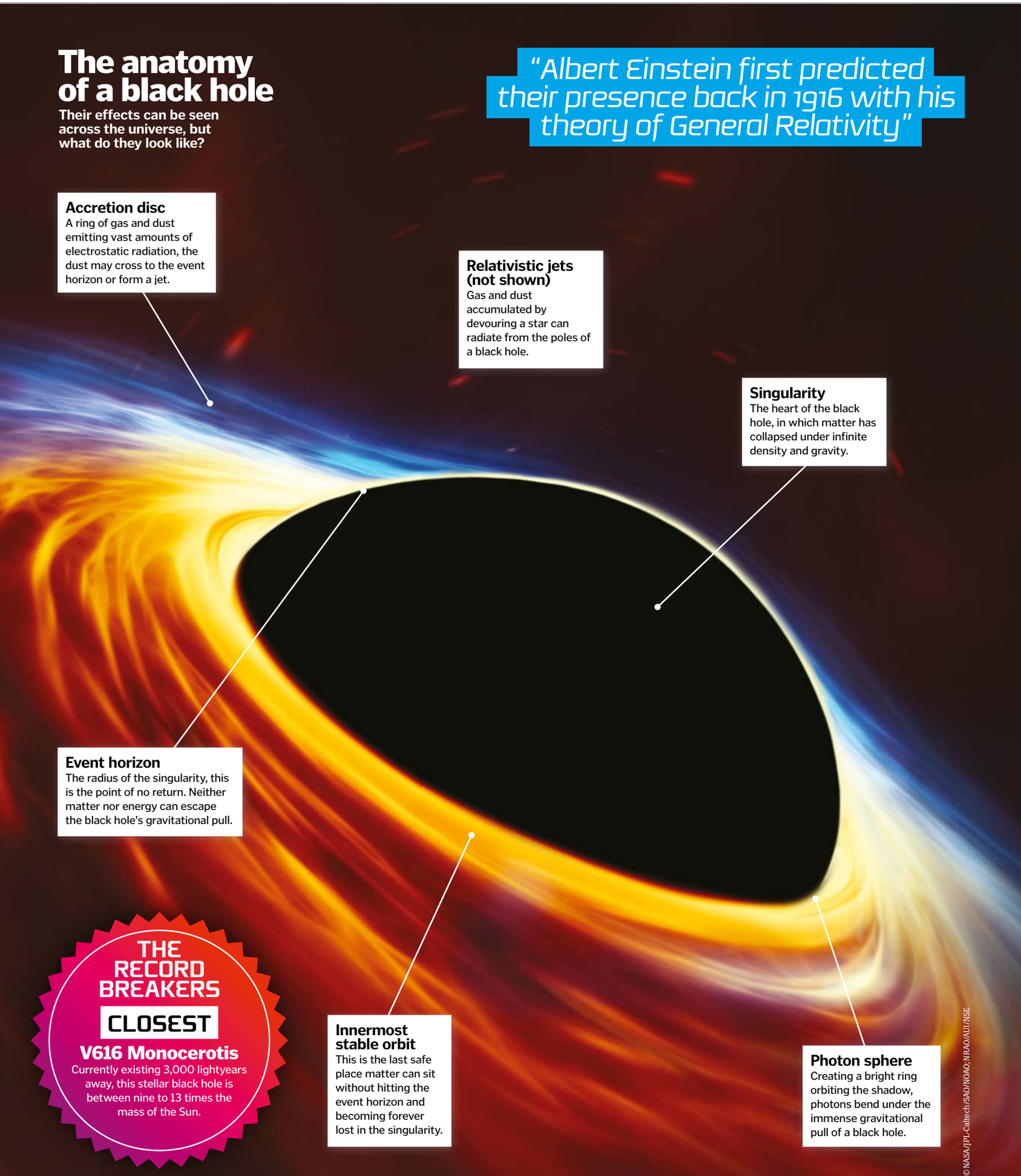


NuStar extends to a ten-metre focus length, detecting higher energies than previous missions Chandra and XMM-Newton

The anatomy of a black hole

Their effects can be seen across the universe, but what do they look like?

"Albert Einstein first predicted their presence back in 1916 with his theory of General Relativity"



Accretion disc
A ring of gas and dust emitting vast amounts of electrostatic radiation, the dust may cross to the event horizon or form a jet.

Relativistic jets (not shown)
Gas and dust accumulated by devouring a star can radiate from the poles of a black hole.

Singularity
The heart of the black hole, in which matter has collapsed under infinite density and gravity.

Event horizon
The radius of the singularity, this is the point of no return. Neither matter nor energy can escape the black hole's gravitational pull.

Innermost stable orbit
This is the last safe place matter can sit without hitting the event horizon and becoming forever lost in the singularity.

Photon sphere
Creating a bright ring orbiting the shadow, photons bend under the immense gravitational pull of a black hole.

THE RECORD BREAKERS

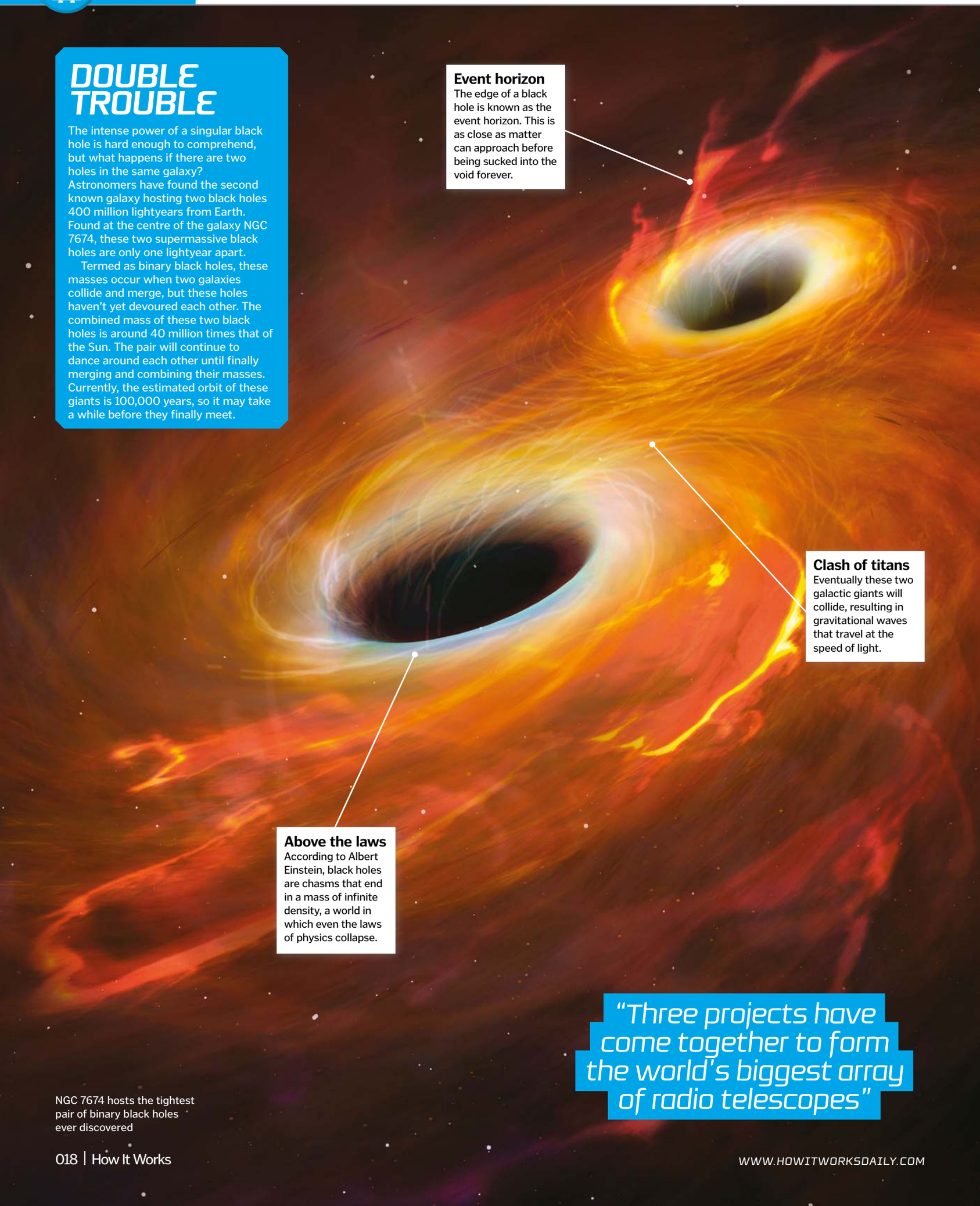
CLOSEST

V616 Monocerotis
Currently existing 3,000 lightyears away, this stellar black hole is between nine to 13 times the mass of the Sun.

DOUBLE TROUBLE

The intense power of a singular black hole is hard enough to comprehend, but what happens if there are two holes in the same galaxy? Astronomers have found the second known galaxy hosting two black holes 400 million lightyears from Earth. Found at the centre of the galaxy NGC 7674, these two supermassive black holes are only one lightyear apart.

Termed as binary black holes, these masses occur when two galaxies collide and merge, but these holes haven't yet devoured each other. The combined mass of these two black holes is around 40 million times that of the Sun. The pair will continue to dance around each other until finally merging and combining their masses. Currently, the estimated orbit of these giants is 100,000 years, so it may take a while before they finally meet.



Event horizon
The edge of a black hole is known as the event horizon. This is as close as matter can approach before being sucked into the void forever.

Clash of titans
Eventually these two galactic giants will collide, resulting in gravitational waves that travel at the speed of light.

Above the laws
According to Albert Einstein, black holes are chasms that end in a mass of infinite density, a world in which even the laws of physics collapse.

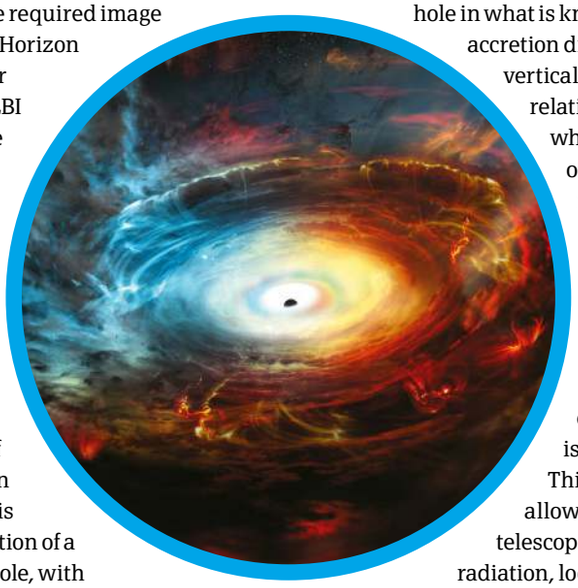
"Three projects have come together to form the world's biggest array of radio telescopes"

NGC 7674 hosts the tightest pair of binary black holes ever discovered

scientists can record the way they orbit a potential black hole. Observing X-ray emissions from black holes has also proven to pinpoint these holes, but it can only get you so far without actually seeing them directly. So how do you catch a glimpse of one?

PEERING INTO THE UNKNOWN

Three projects have come together to form the world's biggest array of radio telescopes and hopefully produce the required image resolution. The Event Horizon Telescope (EHT), sister project Global mm-VLBI Array (GMVA) and The Atacama Large Millimeter/submillimeter Array (ALMA) have turned the Earth into a planet-sized telescope. They will focus their attention on the compact radio source at the centre of the Milky Way. Known as Sagittarius A*, this is thought to be the location of a supermassive black hole, with the equal mass of around 4 million Suns.



Using a technique called very-long-baseline interferometry (VLBI), the array of telescopes are linked together in order to pickup the astronomical radio sources in space. Objects in space emit different radio waves and radiation, including black holes. The radiation can help produce an image: not of the black hole itself, as that would be impossible, but of its event horizon and the accretion disc that encircles it.

As a star, planet, or any matter in any form, crosses the path of a black hole, the sheer magnitude of the hole's gravitational pull will devour it. A meal eaten so aggressively will only leave small bits of debris behind. The dust, gas and plasma that remain are held orbiting a black hole in what is known as the accretion disc and fire vertically to form relativistic jets. This is where the production of electromagnetic radiation and light is generated and shot out of the black hole. When the collision with a star produces a vast amount of energy and light it is known as a quasar. This enormous event allows the array of radio telescopes to detect the radiation, locate the event horizon and finally form a picture of a black hole's shadow.

This planetary collaboration started collecting data in April of this year, and with the last results coming from the South Pole at the end of the year, we could finally see the first image of a black hole at the beginning of 2018.

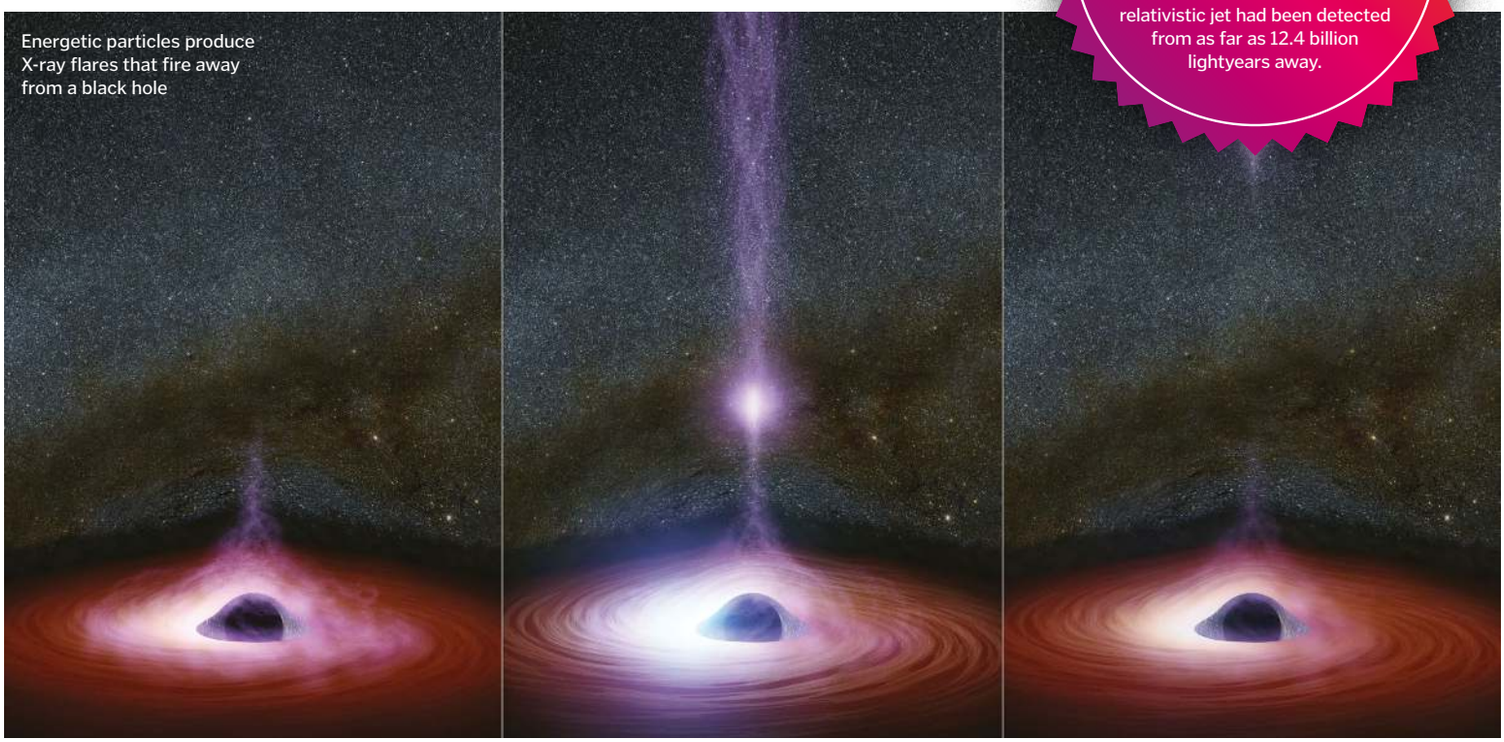
To travel past the event horizon, objects would have to travel faster than the speed of light

THE RECORD BREAKERS

MOST DISTANT

GB 1428

The radiation from a black hole's relativistic jet had been detected from as far as 12.4 billion lightyears away.



Energetic particles produce X-ray flares that fire away from a black hole

A PICTURE IS WORTH A THOUSAND WORDS

Taking an image of a black hole will do more than simply show us what a black hole looks like: it could solidify the theories surrounding the phenomenon.

Einstein's theory of General Relativity describes gravity not as a force but as a curvature of space-time. As a result of his theories, Einstein concludes the shape of a black hole is spherical, while others have suggested the shape to be 'squashed'. It may seem strange to be concerned with the shape of a black hole, but the shape directly correlates to the way the black hole works and how we view space-time.

Imagine a tightly stretched piece of lycra, pinned at each end, with a weighted ball in the middle. This is how we currently view the workings of black holes and space-time by way of general relativity. The denser the mass of the black hole (in this case the ball) the more it affects the lycra (representing space-time). By knowing the shape and mass of a black hole we can better understand the space-time around it.

Theoretical physicist Stephen Hawking also proposed the idea that black holes emit radiation from their mass, sinking the hole and eventually leading to its total evaporation. By imaging Sagittarius A* the EHT can determine its shape and size and the decreasing factors of a black hole. This could cement or adjust these theories and allow us to gain a better understanding of the universe we live in.

It appears that alongside the remains of stars, a multitude of unanswered questions circle black holes, but by catching a glimpse of one scientists could start answering them.

THE RECORD BREAKERS

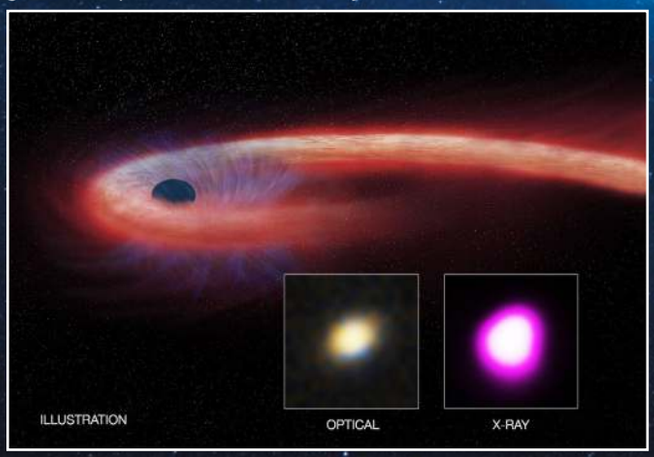
SMALLEST

XTE J1650-500

Estimated to have a mass of around five to ten times that of our Sun, JT650 is 24 kilometres in diameter.

Matter spirals faster and faster as it falls into the gravitational pull of a black hole

Tidal disruption occurs when a star first falls into the gravitational pull of a black hole and X-rays are released

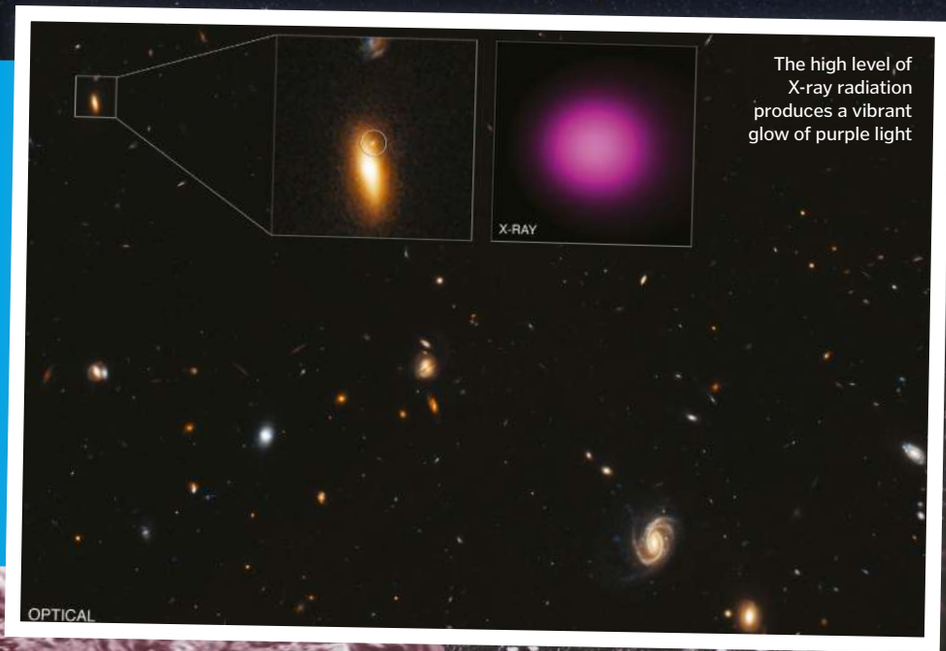


THE LONELY TRAVELLER

Typically supermassive black holes are fixed at the centres of galaxies, but there have been cases of these holes moving around. Known as wandering black holes, these masses are the result of a smaller galaxy falling into a larger one.

The most recent case was the discovery of XJ1417+52, which is 4.5 billion light years from Earth and has the mass of an estimated 100,000 Suns. The giant was found by orbiting telescope missions Chandra and XXM-Newton.

Astronomers have labelled this mass a 'hyper-luminous X-ray source' due to the extraordinarily bright X-rays emitting from it, which are caused by the large amount of dust and gases combined from the collision of two galaxies and the devouring of many stars.



The high level of X-ray radiation produces a vibrant glow of purple light

> *"We could see the first image of a black hole by 2018"*

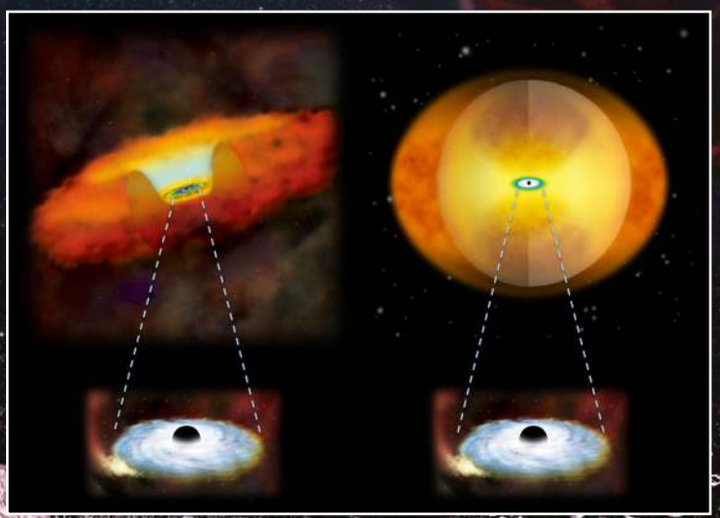
THE RECORD BREAKERS

BIGGEST

Unnamed

Found in the galaxy NGC 1277, 250 million lightyears away, this supermassive black hole's mass is 17 billion times that of the Sun.

When galaxies merge, their black holes become enshrouded in dust and gas



What's happening in 2018?

From Full Moons to the launch of the James Webb Space Telescope, there are many important and exciting events taking place next year

Many moons

As the Moon orbits the Earth its different positions present different lunar phases, which go by various nicknames

New Moon

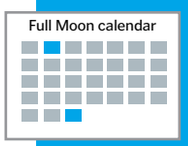
A New Moon has no light reflecting off the lunar surface that faces us. This is because it's positioned between Earth and the Sun.

Full Moon

On the opposite side of a New Moon, a Full Moon occurs when the Moon reflects sunlight off its entire visible surface.

Blood Moon

This only occurs during a total lunar eclipse, because as the Moon enters Earth's umbra the sunlight is scattered by Earth's atmosphere. This presents a blood-like colour on the Moon.



Blue Moon

A Blue Moon is not literally blue; it instead refers to the second Full Moon in the same calendar month.

Supermoon

A Supermoon arises when a Full Moon is at its closest approach to Earth, offering maximum illumination.

January

Icon	Date	Event
	2 & 31	Full Moon / Super Moon / Blue Moon
	3–4	Quadrantids meteor shower
	31	Total lunar eclipse

February

	9–10	European AstroFest
	15	New Moon
	15	Partial solar eclipse

May

	5	InSight probe due to launch
	6–7	Eta Aquarids meteor shower
	9	Jupiter at opposition
	29	Full moon

June

	13	New Moon
	21	Summer Solstice
	27	Saturn at opposition
	28	Full Moon

September

	7	Neptune at opposition
	25	Autumn Equinox
	25	Full Moon
	30	Expedition 57 crew due to travel to the ISS

October

	5	BepiColombo probes due to launch
	TBD (To be decided)	James Webb Space Telescope due to launch
	21–22	Orionids meteor shower
	23	Uranus at opposition

"A Full Moon occurs when the Moon reflects sunlight off its entire visible surface"

Calendar key

Navigating your guide to next year's astronomy events

- Full Moon
- New Moon
- Planetary Event
- Spacecraft Event
- Lunar Eclipse
- Solar Event
- Astronomy Event
- Meteor Shower

March

2 & 31	Full Moon / Blue Moon
9	Expedition 55 crew due to travel to the ISS
15–19	Isle of Wight Star Party
20	Spring Equinox

April

16	New Moon
22–23	Lyrids meteor shower
27	Expedition 56 crew due to travel to the ISS

July

13	Partial solar eclipse
20–22	Bluedot Festival
27	Total lunar eclipse
31	Parker Solar Probe due to launch

August

11	Partial solar eclipse
12–13	Perseids meteor shower
26	Full Moon
17	Venus at greatest eastern elongation

November

5–6	Taurids meteor shower
7	New Moon
17–18	Leonids meteor shower
30	Expedition 58 crew due to travel to the ISS

December

TBD	Bigelow Aerospace's CST-100 Starliner due to launch
13–14	Geminids meteor shower
21	Winter Solstice
21–22	Ursids meteor shower

Different eclipses

Total solar

This eclipse occurs when the Sun is blocked entirely by the Moon.

Annular solar

This occurs when the Moon blocks out the Sun's centre, leaving a ring of sunlight shining.

Partial solar

This occurs when the Moon only covers a segment of the Sun.

Partial lunar

This occurs when only part of the Moon enters Earth's umbra.

Penumbral lunar

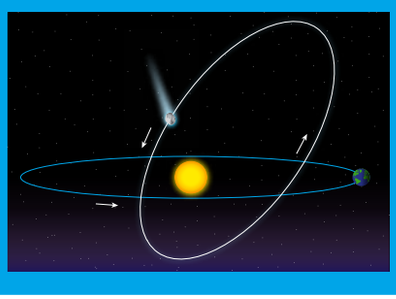
This occurs when the Moon passes through Earth's penumbra, which is the outer and less dark region of the Earth's shadow.

Total lunar

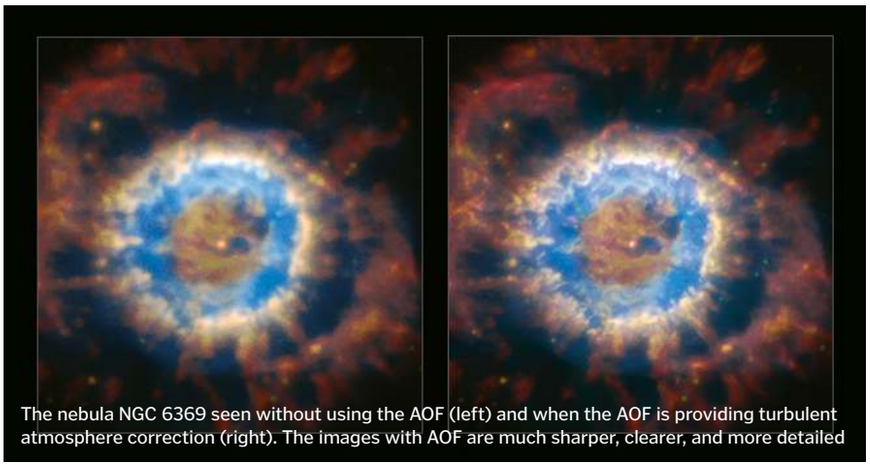
This occurs when the Moon passes in the Earth's umbra (the central and darkest part of Earth's shadow).

Why do meteor showers occur annually?

Meteor showers originate from comets, and similar to how the Earth orbits the Sun, so do comets, but in a more elliptic and aberrant fashion. When Earth's orbit intersects with a comet's orbit its debris creates meteor showers to occur at the same time each year. For example, the Perseids originate from the debris of Comet 109P/Swift-Tuttle, and the Leonids meteor shower is the result of Comet 55P/Tempel-Tuttle.



The lasers provide artificial 'stars' to use as a guide, to track and compensate for the movement of the atmosphere



The nebula NGC 6369 seen without using the AOF (left) and when the AOF is providing turbulent atmosphere correction (right). The images with AOF are much sharper, clearer, and more detailed

ESO's Adaptive Optics Facility

The solution to imaging stars through a turbulent atmosphere

The European Southern Observatory's Adaptive Optics Facility (AOF) is an innovative solution to overcome some of the barriers of ground-based astronomy.

The Earth's atmosphere is a major obstacle for astronomers using ground-based telescopes, as the light from distant stars and galaxies becomes distorted as it travels through the turbulent air, creating indistinct snapshots. This causes inaccuracies in the data retrieved from the images, so stars close together may blur and appear as one. This is where the AOF comes in: it has been engineered to fix this effect in real-time to provide much sharper images and allow scientists to see more subtle details in astronomical objects.

The machine includes four 22-watt lasers that create artificial stars in the upper atmosphere by stimulating sodium atoms there. The adaptive optics module on the ground then uses these artificial stars as a guide to map the turbulence in the atmosphere and sends calculated correction data taken a thousand times per second to the thin, deformable secondary mirror. This mirror can constantly and rapidly change its shape to correct the light that is received from a celestial object, compensating for the atmospheric disturbance.

Using this method astronomers have captured spectacular images of fainter stars with sharper details. It is hoped that the technology will be used to gain more insight into deep space, in particular the formation of galaxies.

How radiation affects astronauts

Space travel is risky business, but not just during launch and re-entry

When we think of the dangers astronauts confront on a mission, we might think that the biggest threat they face would be being hit by a rogue space rock, running out of oxygen or maybe even colliding with space debris. In reality, one of the biggest dangers they face is a silent killer, quietly mutating and destroying their DNA during flight: radiation.

On Earth, we're lucky: we sit under the atmosphere, which blocks cosmic rays and keeps us safe from most of the effects of radiation. But when a human leaves this blanket of protection, their body is vulnerable to being blasted by high-energy particles. Scientists don't fully know the effects space radiation has on the human body, but we can learn a lot by using animal models and by studying astronauts during and after a mission.

Brain damage

Studies in small mammals exposed to space radiation suggest changes to memory, inflammation of the brain, shape of brain cells, and an affect on the production of new cells.

Cataracts

Several Apollo astronauts reported seeing light flashes, likely caused by heavy ion interactions with the retinal photoreceptors in the eye as cosmic ray nuclei penetrates their head and eyes. They are at higher risk of cataracts too.

Cosmic rays: space's silent killer

How are these high-energy particles damaging astronauts' bodies?

Cardiovascular disease (CVD)

Studies on astronauts that have returned from their missions have shown that the amount of CVD-related deaths is much higher. Astronauts who have flown to the Moon are four to five times more likely to die from CVD than those who have never left Earth's atmosphere.

Cancer

Ionising radiation can cause cancerous mutations at 50mSv (millisieverts) and above, yet astronauts are exposed to approximately 50–2,000 mSv on a six-month mission.

Communicating with the ISS

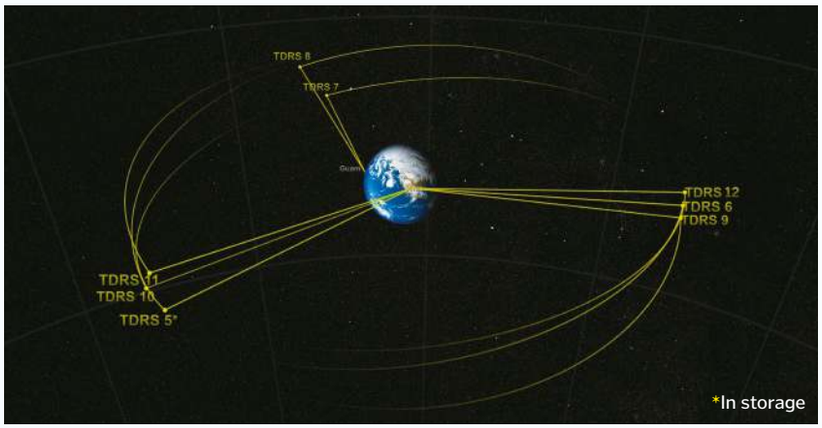
How do astronauts on the space station stay in touch with Earth?

If you've ever suffered patchy phone signal on a train journey, you'll know that high-speed travel and consistent network coverage do not go together. As your phone tries to switch between the closest available network masts, signal can fluctuate and make communication unreliable. But what if instead of being on a train you're orbiting Earth at over 27,500 kilometres per hour, and a loss of communication could be the difference between life and death? These are the stakes on the International Space Station.

Regular contact between the astronauts and ground control is vital for the proper running of the station and the safety of the astronauts onboard. However, signals can't reliably be sent directly between mission control and the ISS via a single transceiver on Earth. Radio waves would not be able to travel through the Earth itself, so while the station travels over the other side of the planet, it would spend a significant proportion of its 90-minute orbit out of the transceiver's range.

To solve this problem NASA uses the Tracking and Data Relay Satellite System (TDRS), a network of satellites that send and receive signals between the ISS and various ground stations on Earth. The seven active satellites that currently make up the TDRS are in geosynchronous orbit, positioned around the globe to provide continuous coverage to the ISS.

When astronauts need to contact mission control, their signals are sent from the ISS to the closest satellite in the TDRS constellation. The satellite then relays the signal to the ground station below, where it can be forwarded on to the relevant mission control centre.



There are currently seven active TDRS satellites in orbit. The ninth, TDRS-M, launched in August 2017 and is due to enter service soon

Continuous cosmic coverage

How does the TDRS network prevent communication blackouts?

Global coverage
The TDRS satellites are positioned above the Atlantic, Pacific and Indian oceans.

Tracking and Data Relay Satellite

Two-way communications

Two-way communications

Two-way communications

TDRS space-to-ground link

Hubble Space Telescope

Other missions
The TDRS also facilitates communication and data transfer to and from other low-Earth orbit missions like Hubble, as well as remote bases like the Amundsen-Scott South Pole research station.

1. Calling Earth
If astronauts need to contact mission control, their message is sent as radio waves to the nearest TDRS satellite.

Keeping in touch
Reliable communication between the ISS and Earth is vital for the everyday running of the station and the safety of the astronauts.

2. Relaying the message
The message from the ISS is received by the TDRS and relayed to a ground station on Earth.

4. Two-way link
When mission control need to contact the space station, the process works in reverse. Signals are sent to the ground stations, where they are transmitted to the TDRS for relay to the ISS.

White Sands Complex
New Mexico

3. Message received
The ground station relays the signal to the mission control centre it is intended for.

International Space Station

10 INVENTIONS TO CHANGE THE W

THE TECHNOLOGICAL BREAKTHROUGHS THAT MIGHT LEAD TO A BETTER TOMORROW

1 ARTIFICIAL INTELLIGENCE

If there's one thing that elicits thoughts of the future, it's artificial intelligence (AI). But AI is already changing our lives in more ways than you might think, such as stopping violence and flying our planes.

Driverless cars might hog the headlines, but in June 2017 Boeing tested an autonomous plane that could take off, cruise and land with little human input. Whether a self-flying cockpit would be trusted by the public is another matter, but most are already comfortable with autopilot technology, so who knows where this may go.

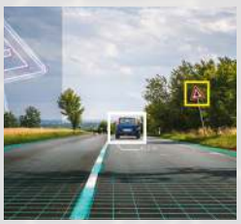
A company out in the US called ShotSpotter, meanwhile, has been looking at using acoustic sensors to pinpoint the location of gunfire during a shooting or crime. Machine learning confirms that a gun produced the sound and then counts how many there are, telling police what to expect.

These are just some of the many ways AI might change our lives in the coming years.

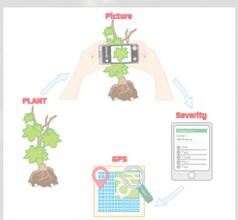
AI applications

Tackling violence
Using machine learning and acoustic sensors, ShotSpotter can pinpoint a gun firing within 25 metres and alert the authorities.

Detecting cancer
Using images from a smartphone, AI can detect skin cancer, then diagnose conditions with the accuracy of a dermatologist.



Safer driving
IBM Research are working on the use of 'hyperimaging' and AI. This tech could be used in cars to help drivers to see through fog and other bad weather conditions.



Fighting famine
The Mcrops project plans to use smartphones and computer vision to spot signs of disease in cassava crops, a staple food source for over 500 million people.

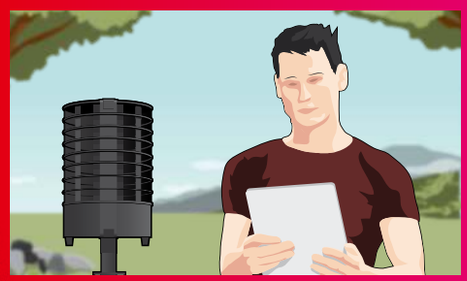
TIONS WORLD

2 HI-TECH MOSQUITO TRAPS

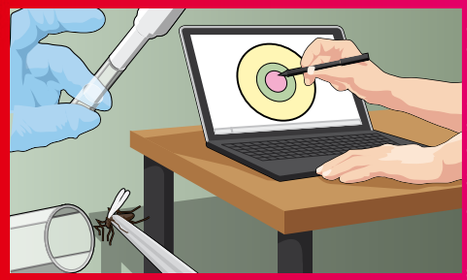
What if we could stop diseases before they spread? That's the goal of Microsoft's Project Premonition, which hopes to prevent epidemics like the Zika virus from taking countless lives. The idea is to use mosquitoes as the ultimate field biologists. By setting up specialised traps in hot spot areas, mosquitoes will be captured and then studied, analysing what viruses — if any— they are carrying. Ultimately the team hopes to use drones to identify hot spots.

The traps have smart compartments equipped with infrared laser beams. When the flutter of a mosquito's wing is detected, the compartment automatically shuts its door, trapping the mosquito for later study. An algorithm can then determine the species by scanning the bug, taking into account the time of day and the amount of light available, before the data is then transmitted to researchers. It's hoped this can be used to spot outbreaks before they spread.

1 Find
Autonomous drones are used to find hot spots of mosquitoes in a particular area and then drop traps down to collect them.



2 Collect
The robotic traps use infrared light to detect the species of mosquito. If it's one of interest the door shuts and the bug can then be analysed.



3 Detect
Scans check the blood of the mosquitoes for harmful pathogens and see what animals it has bitten, helping to predict how a disease may spread.

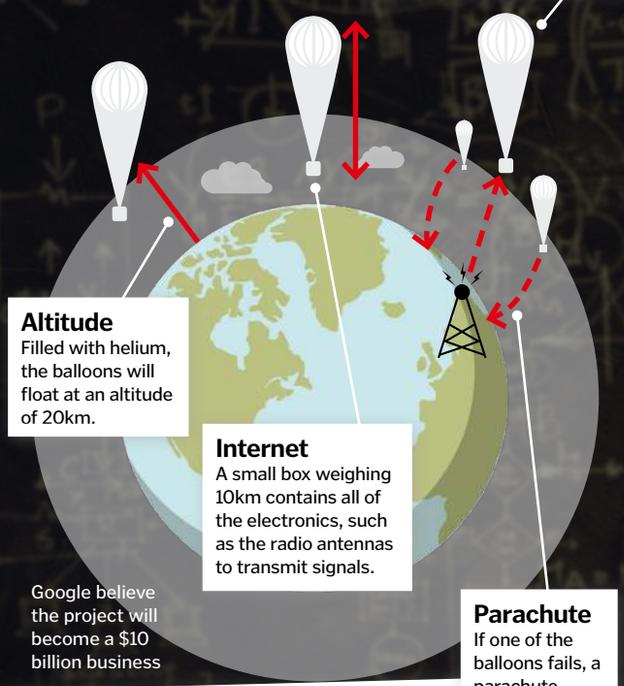
3 GLOBAL INTERNET ACCESS

What if you could access the internet anywhere in the world? That's the idea behind Project Loon, Google's ambitious project run by its secretive X branch to create a global web. The plan is to use high-altitude balloons 20 kilometres up to transmit Wi-Fi to the ground, bringing connectivity to the remaining portions of the world that aren't currently online.

Filled with helium, the balloons are about 15 metres across. Beneath them hangs a small box that enables the Wi-Fi signal to be transmitted to the ground. Running on solar power, the balloons can stay aloft for up to 200 days. It's not yet clear when the service might come online, although a pending patent dispute may delay efforts somewhat. Originally planning to build hundreds, Google now says it can bring the system online with just dozens, using machine learning to direct the balloons to certain areas.

Project Loon

How Google plans to bring the whole world online



Balloons
Dozens of the balloons could hover over a region to bring internet to remote areas.

Altitude
Filled with helium, the balloons will float at an altitude of 20km.

Internet
A small box weighing 10km contains all of the electronics, such as the radio antennas to transmit signals.

Parachute
If one of the balloons fails, a parachute brings it gently to the ground and its helium is expelled.

Google believe the project will become a $10 billion business

Pollinator drones could support bees in transporting pollen to plants

4 POLLINATOR DRONES

It might sound like an episode of *Black Mirror*, but researchers have begun using insect-sized drones to pollinate flowers in place of bees. The idea is not necessarily to replace bees but to compliment them as agricultural needs increase.

Researchers at the National Institute of Advanced Industrial Science and Technology (AIST) in Japan unveiled the drones in early 2017, which use a special ionic gel to attach onto pollen. The team flew drones that dangled bristles made of horse hair (like a bee's fuzzy exterior) laden with this gel. In tests on Japanese lilies, the team found the drones were able to successfully begin the process of seed production.

The research still has a long way to go, but the potential benefits are plain to see. While we shouldn't turn a blind eye to bee decline, this research provides a promising back-up as needs increase.

One honeybee colony

POLLINATES 4,000m² of fruit trees

IT TAKES 12 bees a lifetime's work to make one teaspoon of honey

CAN POLLINATE 300 MILLION flowers in a day

CONTAINS AROUND 50,000 BEES

BEES POLLINATE 70 TYPES of crop in the UK alone

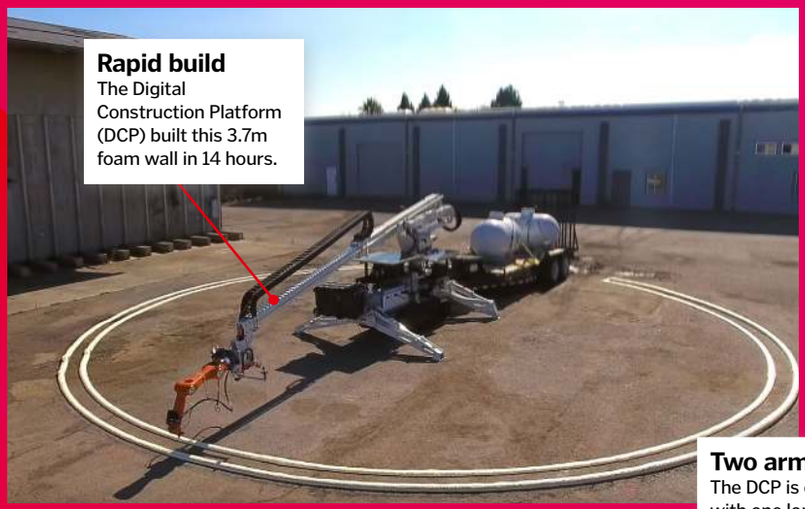
BEES ARE WORTH £112.5 BILLION to agriculture per annum

30% of all food relies on pollinating insects

60% reduction in hives between 1947 and 2008 in the US

HONEY HONEY HONEY HONEY HONEY HONEY HONEY HONEY HONEY HONEY HONEY HONEY HONEY HONEY HONEY

GENERATES AROUND 15KG OF HONEY EACH YEAR



Rapid build
The Digital Construction Platform (DCP) built this 3.7m foam wall in 14 hours.

Two arms
The DCP is equipped with one long, 5-axis hydraulic arm that has a shorter 6-axis arm mounted on its endpoint.

Dynamic
The DCP can be used to pour concrete, spray insulation or be equipped with a milling head.

Novel 3D-printing techniques could be used to construct entire buildings

Below and left: if you need windows, MIT has also been working on 3D printing glass

5 { 3D-PRINTED BUILDINGS }

Sure, 3D-printed toys and tools are pretty cool. But printing an entire building would be a whole let better, and that's what a team from MIT is working on. Their robotic system uses a vehicle with tracks to carry a large, industrial robotic arm. A nozzle at the end can then be used to lay concrete or spray insulation, allowing a structure to be built up over time.In a test they were able to build a dome made of polyurethane foam moulds filled with concrete in 14 hours, measuring 3.7 metres high and 15 metres wide.

The idea is that these machines could optimally build structures using on-site environmental data, such as giving walls varying thickness depending on which way they are facing. It's still in its early stages, but one day you might be stepping into a 3D-printed home.

6 SUPER BATTERIES

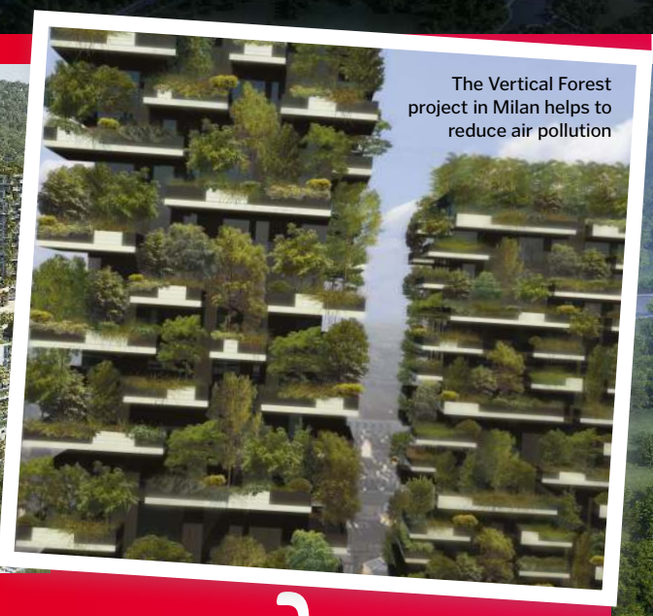
A number of breakthroughs in battery technology could lead to ones that are longer-lasting and charge faster. In July 2017, a team of scientists from the Korea Advanced Institute of Science and Technology (KAIST) came up with a novel solution to the former by using 'molecular pulleys' to increase lifetime. These held silicon inside the battery's anode in place, allowing it to remain 98 per cent effective even after hundreds of cycles.

In 2015, meanwhile, Samsung unveiled a new rapid-charging technology that could recharge a phone in minutes. They used synthesised organic molecules inside their batteries to achieve the results, with ions moving more quickly in these batteries than others and thus charging faster.

And if capacity is your thing, we've got you covered. In 2016, scientists from the University of Central Florida (UCF) revealed their supercapacitor battery prototype, using metal materials the width of an atom wrapped in nanowires to greatly increase storage capacity.

Advanced batteries could charge in a matter of minutes

International idea
The concept for the Forest City was designed by Milan-based Stefano Boeri Architetti.



The Vertical Forest project in Milan helps to reduce air pollution

7 SMOG-BUSTING BUIDINGS

Smog is a serious issue in cities across the globe, threatening the health of many people. But steps are underway to tackle it using some innovative new technologies that can pull it out of the air.

One such idea is the Vertical Forest project in Milan. This pair of residential towers hosts 20,000 trees and plants to absorb nearly 20,000 kilograms of carbon dioxide every year and turn it into oxygen. The trees can also keep the temperatures of buildings down and filter out dust particles from traffic. Specialised aerial arborists scale the buildings to keep the plants and trees fed and watered.

Similar projects have since sprung up in China (the Liuzhou Forest City), Canada and elsewhere. While one would hope the problem of pollution might be stopped at the source by reducing emissions, these at least offer another solution.

"Smog is a serious issue in cities across the globe, threatening the health of many people"

Leaves by the line
The city will be equipped with a futuristic train line and spaceship-like train station.

Green travel
In line with the eco-friendly surroundings, the cars on the roads will be electric.

Among nature
The Liuzhou Forest City will be home to 30,000 people and around 40,000 trees.

8 WATERLESS TOILETS

Waterless toilets might not sound too appealing, but they could be a hugely important health breakthrough across the globe. More than 2.4 billion people live without access to clean running water, and approximately 1.5 million children die each year from food and water that has been tainted with faecal matter.

In 2012 the Bill and Melinda Gates Foundation sought to change all that, awarding funding to several teams developing waterless toilets. Now one of those, the Nano Membrane toilet from Cranfield University in the UK, is making strides.

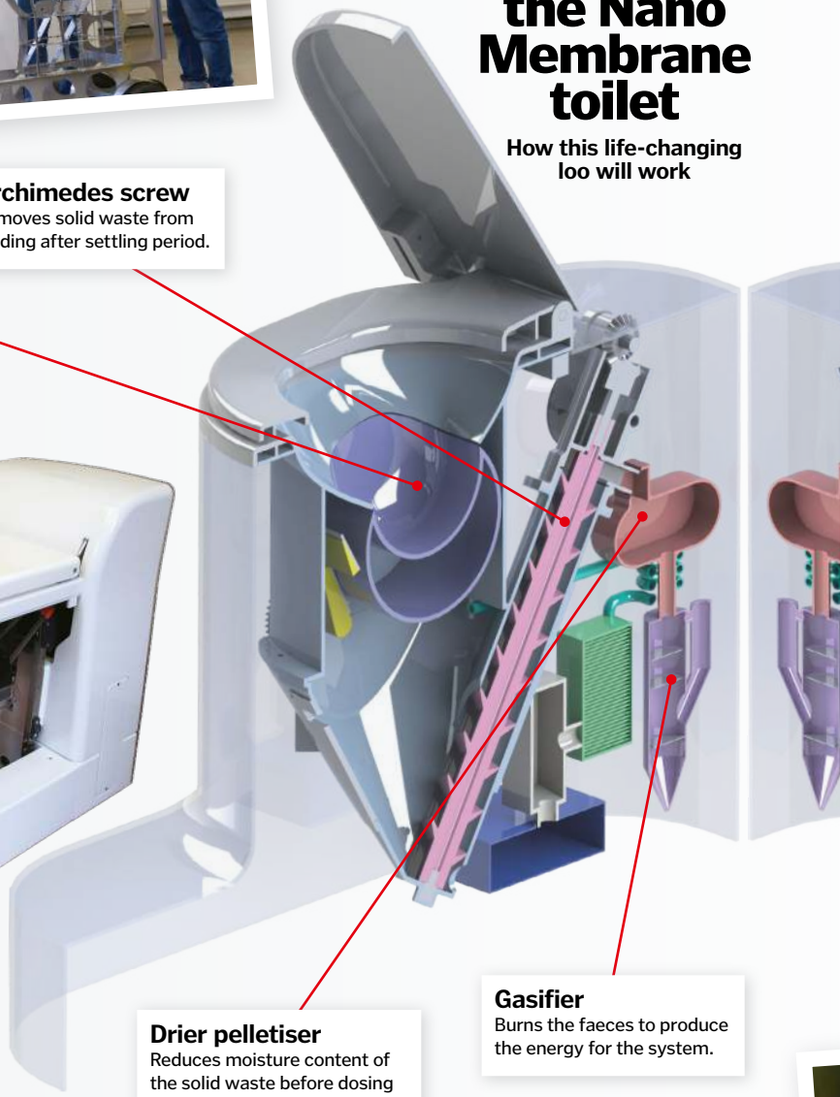
Using nanotechnology, their device directly converts human waste into water and ash. The water is removed from urine by passing it through a membrane chamber and heating it, while faeces is burned to turn it into useful ash. The team are hoping to begin field testing their idea, which could be a game-changer for many.

Inside the Nano Membrane toilet

How this life-changing loo will work

Rotating flush
Waste enters the toilet as normal in a mixed stream. A rotating waterless flush blocks odour and transfers the waste into the holding tank for separate processing of urine and faeces.

Archimedes screw
Removes solid waste from holding after settling period.



Spending a penny
While the toilet will cost around $2,500 (£1,880), by serving 50 users a day that price equates to 5¢ (4p) per person per day for ten years.

Drier pelletiser
Reduces moisture content of the solid waste before dosing the fuel into the gasifier below.

Gasifier
Burns the faeces to produce the energy for the system.

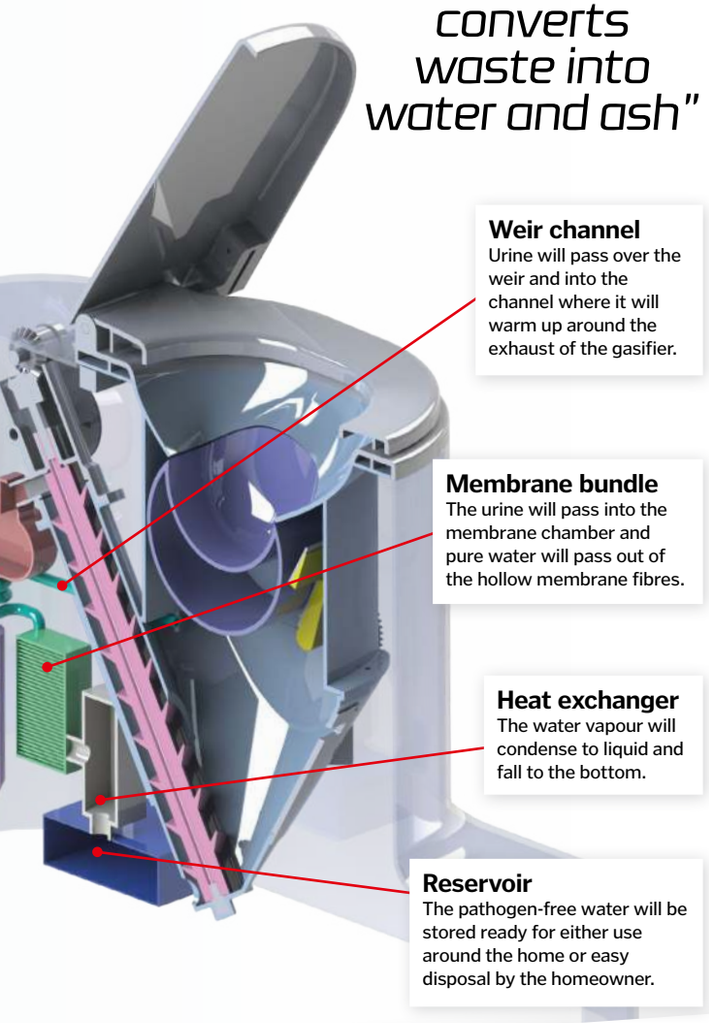
9 BIODEGRADABLE PLASTICS

Plastic waste is a huge problem, taking centuries to degrade when discarded in landfills. Biodegradable plastics, however, could be a lifesaver. Using materials that break down in much shorter periods of time, the wastage problem could be dramatically reduced.

One idea comes from researchers at Harvard, who created a bioplastic from a substance found in shrimp shells. The substance is chitosan, a form of a polymer called chitin that's responsible for the hardiness of shrimp shells. It is the second most abundant organic material on Earth, so there's no short supply. It breaks down in just weeks, leaving behind nutrients that can support plant growth.

Another idea comes from the Indonesian company Avani, who have made plastic bags and other objects out of cassava starch, a shrub found in South America. Their resultant bioplastic is completely biodegradable and compostable. Looking indistinguishable from regular plastic bags, these might just be the future of shopping.

"The device converts waste into water and ash"



Weir channel
Urine will pass over the weir and into the channel where it will warm up around the exhaust of the gasifier.

Membrane bundle
The urine will pass into the membrane chamber and pure water will pass out of the hollow membrane fibres.

Heat exchanger
The water vapour will condense to liquid and fall to the bottom.

Reservoir
The pathogen-free water will be stored ready for either use around the home or easy disposal by the homeowner.

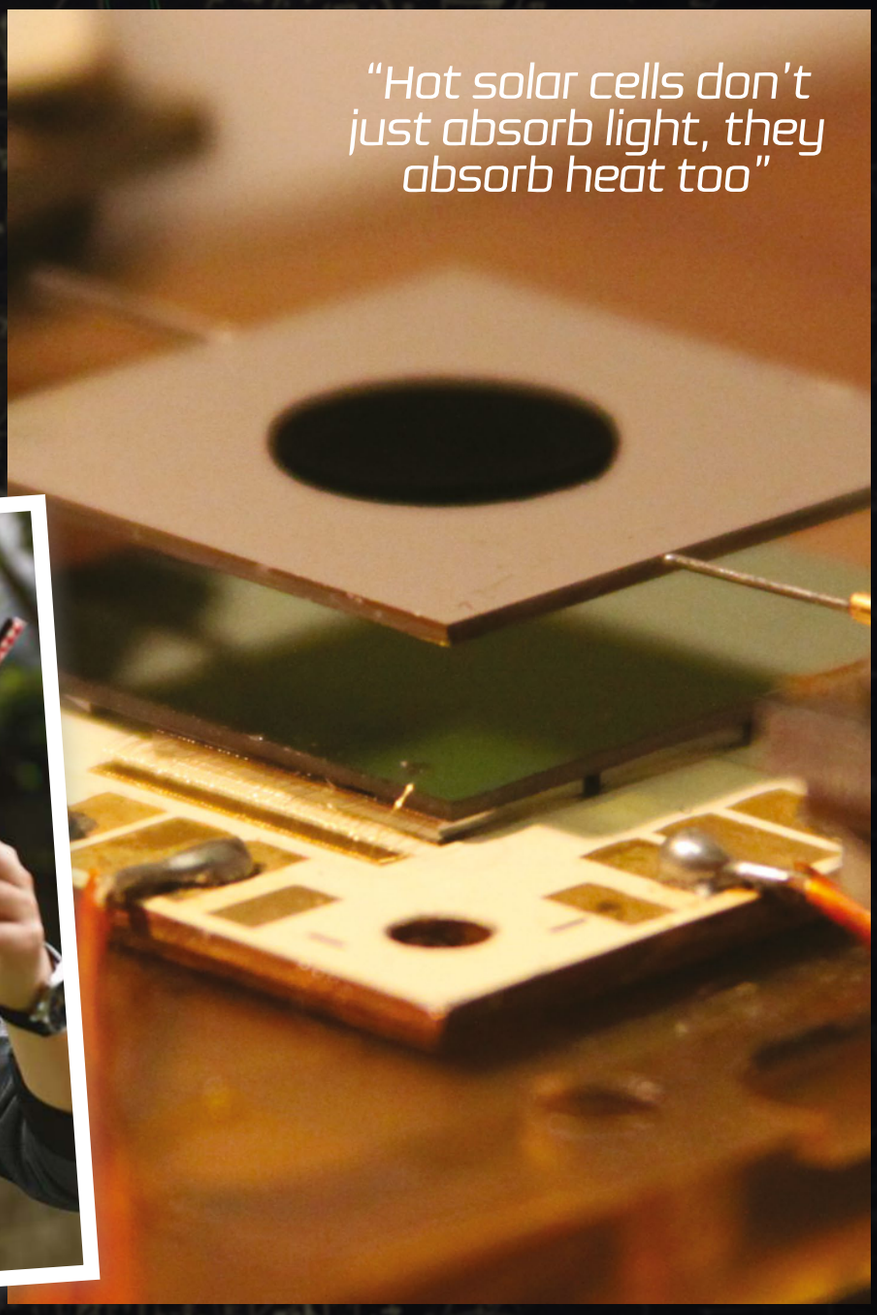
Avani's eco bags, cups and other implements are made from cassava starch

10 { ADVANCED SOLAR POWER }

While solar power is becoming increasingly widespread, one problem is that solar cells are not that efficient, being able to convert only around 32 per cent of incoming sunlight into electricity. However, that could all change with hot solar cells, which could double the efficiency.

The idea is not just to absorb light but to absorb heat too. So-called thermophotovoltaics have been around for a while, but in 2016 a team from the Massachusetts Institute of Technology (MIT) worked out how to boost their efficiency. They made the spectrum of the incoming light more useful for the solar cell, first by converting it into heat and then back into light. This is the first design to absorb more energy than a standard solar cell. The technology may still be a decade away, but the potential benefits are enormous.

"Hot solar cells don't just absorb light, they absorb heat too"



Laser hair removal

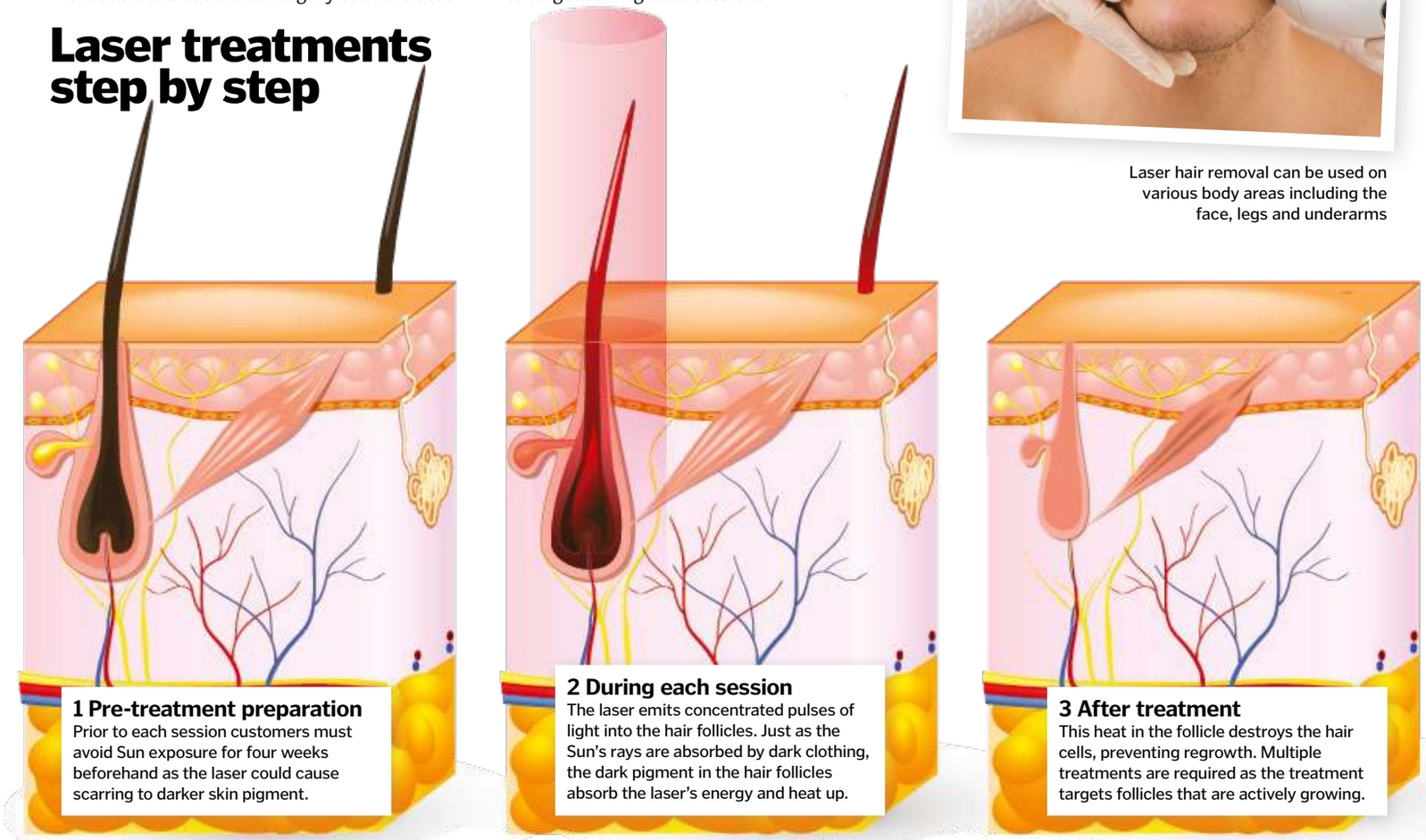
How does light help to get rid of unwanted hair?

Silky smooth skin has been in fashion since the Middle Ages, so it's no surprise that countless methods have been developed over the years, with varying levels of success. Despite first launching three decades ago, there is one technique that is still considered at the top of the hair removal game: laser removal.

For the most part, laser hair removal still works as it did back then. Highly concentrated pulses of light at specific wavelengths target and are absorbed by the dark pigment in hair follicles called melanin. The follicles heat up and are destroyed, preventing future regrowth. It's most effective on darker and coarser hair, with best results achieved via six to ten monthly treatments. This is because each hair goes through a natural growth cycle with a 'rest' and 'fall-out' phase, meaning not every hair is there to target during each session.

Laser hair removal can be used on various body areas including the face, legs and underarms

Laser treatments step by step



1 Pre-treatment preparation
Prior to each session customers must avoid Sun exposure for four weeks beforehand as the laser could cause scarring to darker skin pigment.

2 During each session
The laser emits concentrated pulses of light into the hair follicles. Just as the Sun's rays are absorbed by dark clothing, the dark pigment in the hair follicles absorb the laser's energy and heat up.

3 After treatment
This heat in the follicle destroys the hair cells, preventing regrowth. Multiple treatments are required as the treatment targets follicles that are actively growing.

HOW TO SPOT FAKE NEWS

Separate the facts from the fiction with our quick checklist

Source
Investigate the site; look for its mission and contact information.

URL
Does the URL look legitimate? Search the domain name to identify if there are multiple sites with similar URLs.

Date
News stories may be reposted, making them irrelevant to current events.

Author
Search the author's name. Are they real? What have they written previously?

Similar stories
Has the story been reported by other credible news sources?

Content
Read past the headline — is the content satire or serious. Are the interviewees real?

Images
Are the pictures in the story real or edited? Reverse search the images and see where else they have been used.

Bias
Do your own views or opinions affect your judgment on the stories validity?

Desalination plants

How salty seawater is turned into drinkable fresh water on an industrial scale

Our planet is covered in water, but countries the world over struggle with drought because over 96 per cent of this precious liquid is found in the oceans and is therefore completely undrinkable.

Seawater is more than three per cent salt. If we try to consume it our kidneys go into overdrive, filtering out the excess sodium and passing it out as urine. But there's a problem — drinking water straight from the ocean makes you more dehydrated than drinking nothing at all. Kidneys can't make urine as salty as seawater, and to get rid of the salt from one glass you need to produce more than one glass of pee.

The solution is desalination, a process that removes salt from seawater to make it drinkable, either using a boiling technique called multistage flash or a filtration method known as reverse osmosis.

Multi-stage flash uses the same principle as a solar still: as water boils, pure vapour evaporates, leaving salt crystals behind. The vapour can then be collected, condensed and used for drinking.

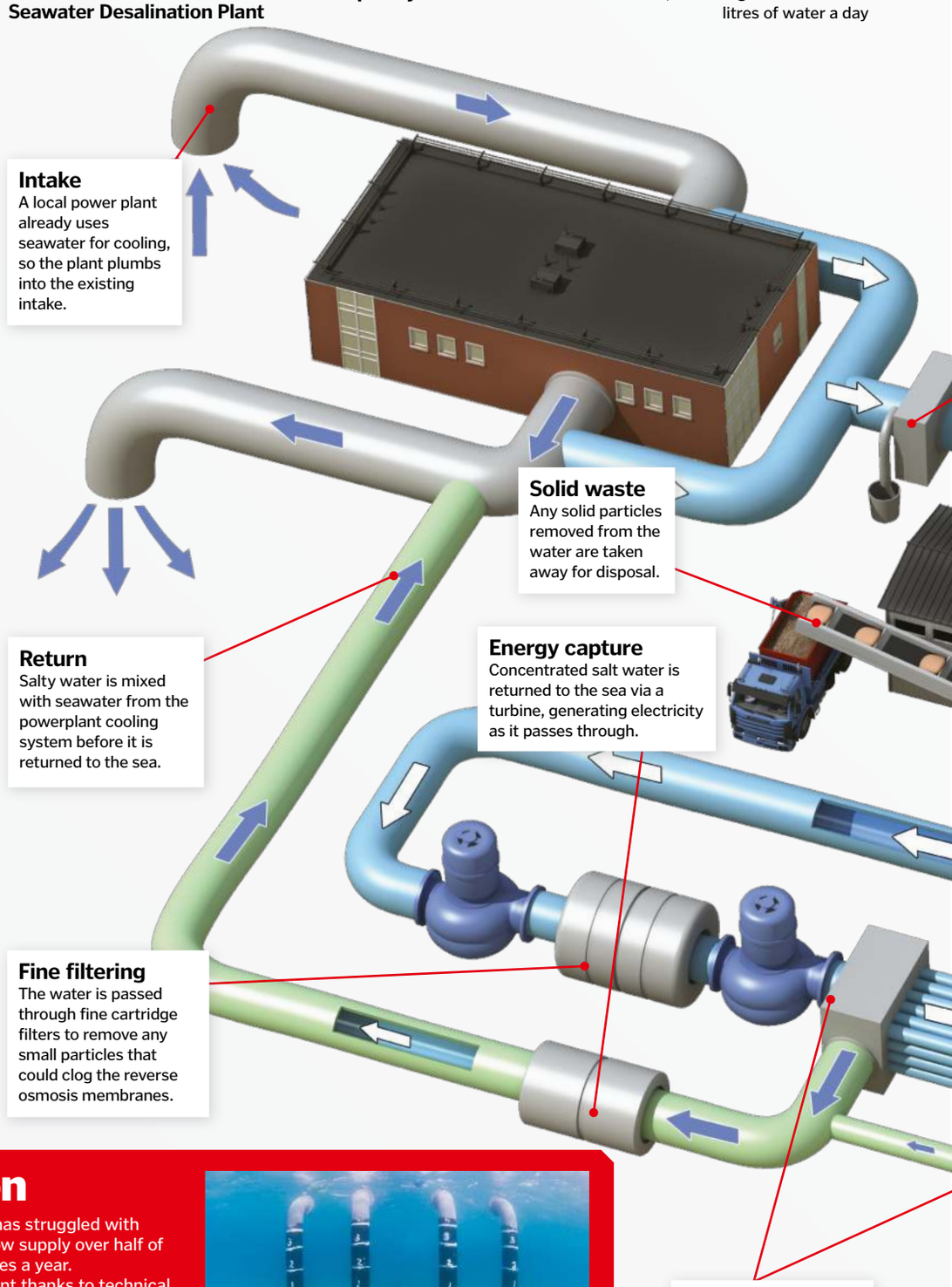
Reverse osmosis filters the water to remove the salt, putting the liquid under high pressure against a membrane that only allows the water molecules to pass. Water is forced across, leaving a salty brine on one side of the membrane and clean water on the other.

According to the International Desalination Association, there are now more than 18,000 desalination plants worldwide, supplying over 86 billion litres of water to 300 million people in more than 150 countries every day.

The Carlsbad plant in California is the largest desalination facility in the US, delivering over 227 million litres of water a day

The desalination process

Take a look under the hood of the Tampa Bay Seawater Desalination Plant



Intake
A local power plant already uses seawater for cooling, so the plant plumbs into the existing intake.

Solid waste
Any solid particles removed from the water are taken away for disposal.

Return
Salty water is mixed with seawater from the powerplant cooling system before it is returned to the sea.

Energy capture
Concentrated salt water is returned to the sea via a turbine, generating electricity as it passes through.

Fine filtering
The water is passed through fine cartridge filters to remove any small particles that could clog the reverse osmosis membranes.

Reverse osmosis
Filtered seawater is passed across semipermeable membranes under pressure, separating the water from the salt.

Desalination in action

Israel is one of the driest places on the planet and it has struggled with droughts for decades, but four desalination plants now supply over half of the country's water, producing around 600 billion litres a year.

Desalination is becoming cheaper and more efficient thanks to technical advances; the pipes in Israel's plants are wider than normal, allowing more water to be filtered; there are new chemical treatments to stop algae from clogging up the filter pores; and as much energy as possible is recovered as the water returns to the sea.

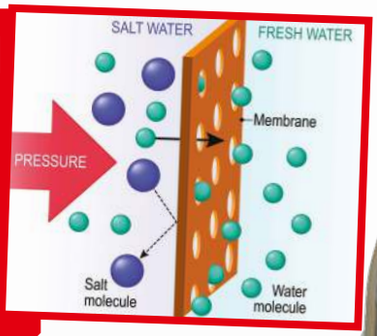
The country used to rely on rainfall, but it's now home to the largest reverse osmosis plant in the world, and most of its water is sourced from the Mediterranean Sea.

These pipes return brine to the Mediterranean Sea once the desalination process is finished

Reverse osmosis explained

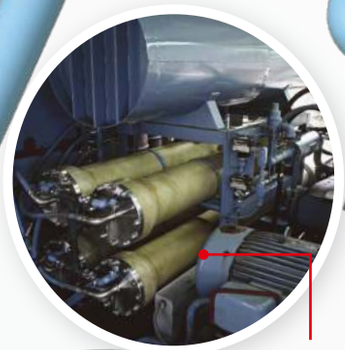
Osmosis is the movement of water from a less concentrated solution to a more concentrated solution through a partially permeable membrane. It's what causes your fingers to swell up and wrinkle if you spend too long in the bath, or slugs to shrivel up if you cover them in salt. And, if you apply pressure, you can make the process happen in reverse.

Desalination plants have membranes covered in pores that measure less than 1/100,000th of the width of a human hair. When pressure is applied, water passes through, but salt is too big to pass, allowing freshwater to be squeezed from brine.



Cleaning
The water is passed through multimedia filters containing pebbles, sand and other rocks, trapping any big particles.

Treatment and blending
The water is treated and blended before entering the general water supply and arriving in people's homes.



Reverse osmosis membranes are wrapped in layers inside these pipes in the US Virgin Islands

"If we try to consume seawater, our kidneys go into overdrive"

Window glazing

How do double and triple glazed windows help keep our homes warm?

Modern double-glazed windows consist of two layers of glass bonded together in one frame, allowing for better insulation and fewer drafts, meaning cheaper heating bills and a quieter home.

A single-pane window can transfer heat through conduction, convection and radiation. This is why on a cold day a single pane of glass can feel much colder than the air. So how are insulating glass windows engineered to reduce the loss of heat from a house? The trick is filling the gap between the panes of glass with air. By providing a blanket of dehydrated air, the rate of heat loss through the window is reduced because air is a poor thermal conductor.

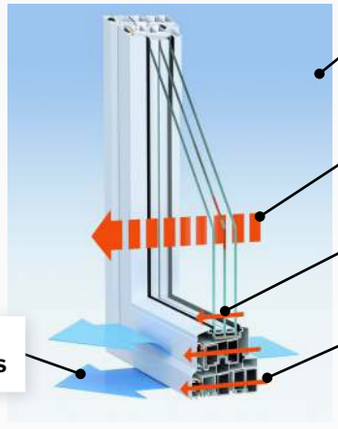
Double glazing has been on the market for over 40 years, and triple-pane glass is becoming increasingly popular. Triple-glazed windows consist of three panes of glass separated by two air chambers. The two external glass surfaces also have a low-e (low emissivity) coating to reflect infrared light. This helps to stop up to 97 per cent of the thermal energy from being transferred across the panes, reflecting the heat instead.

This undoubtedly makes a difference. The efficiency is measured by recording the surface temperature of the glass. The PassivHaus Institute in Germany tested this and found that when the internal temperature of a room is 21 degrees Celsius on a cold day, the internal surface temperature of a single pane is approximately one degree Celsius. However, they found that a traditional double-glazed window would see temperatures nearer 11 degrees Celsius, whereas triple glazing has a surface temperature of 18 degrees Celsius.

Thermograms detect infrared radiation and can help identify areas where the most heat is lost (shown in yellow and orange)

Double vs triple glazing

How do multiple window panes help to reduce heat loss?



Heat loss
Heat is lost via conduction, convection and radiation. Tiny gaps between the window frame can also allow warm air to leak out.

Radiation through glazing

Conduction through glazing spacers

Low-e coating
A thin coating on the outer surfaces of the glass allows natural light to pass through glass while blocking most of the ultraviolet and infrared rays.

Glass
Glass is a relatively good insulator of heat, but due to its transparency thermal energy is easily lost via radiation.

Air leakage between frames

Conduction through window frame

"Triple-pane glass is becoming increasingly popular"

Air chamber
Filled with either dehydrated air or an inert gas such as argon, xenon, or krypton, this helps to reduce heat conduction through the window.

Double glazing
A double-glazed window reflects around 90 per cent of the incident infrared light.

Triple glazing
An additional pane improves efficiency, so triple-glazed windows reflect around 97 per cent of the incident infrared light.

Powerball® — where science meets exercise

Feel the force of 20,000rpms inside your hand powered only by yourself!

A Powerball® is a gyroscopic hand exerciser that uses inertial resistance (gyroscopic precession) in order to strengthen your hands, wrists and arms.

Inertial resistance is the force that fights against you when you try to change the direction of any spinning body. Inside a Powerball® a rotor (wheel) spins freely on its axle. Once spinning, this rotor wants to continue facing the same direction. With Powerball® you turn your wrist in a circular motion; changing the direction of the rotor through turning your wrists creates inertial resistance. The spinning rotor in a Powerball® creates an almost magnetic-field-like feeling against the user. The faster the Powerball® rotor is spinning the more inertial resistance generated against the user, which can be over an incredible 60+ pounds (27 kilograms).

The Powerball® also lives up to its name as the rotor through magnetic induction can power multi-coloured LCD lights and a digital counter that can track your strength gains and the rpms of the Powerball®.

Powerballs are used by everyone from professional athletes looking to improve grip strength to astronauts as training aids in zero gravity or even professional musicians looking to build endurance and stay healthy while playing. The Powerball® gyroscope is also a world-class rehabilitation tool due to the 100 per cent non-impact isometric nature of the resistance exercise it provides.

280Hz Autostart Pro Fusion

Meet the Premium Autostart Powerball® with digital speed counter and multi-colour LEDs

Controlled power
Weighs under 500g but develops up to 30kg of gyroscopic resistance focused directly on your arms and wrists.

Automatic starting
It's easy to start the gyroscope with wind back and release technology.

Drop resistant
A patented shock-absorbing shell design allows Powerball® to absorb those little accidents with ease.

Battery-free digital counter
Track your rpm spin speeds. Can you beat over 17,000rpms — the world record — with this model?

Speed... is personal
Build muscle or rehab a painful arm or wrist injury — it's all about how fast you spin.

Multi-colour rotor LEDs
Watch the rotor lights change colour as your spin speed increases. No batteries needed as the rotor is powering the lights.

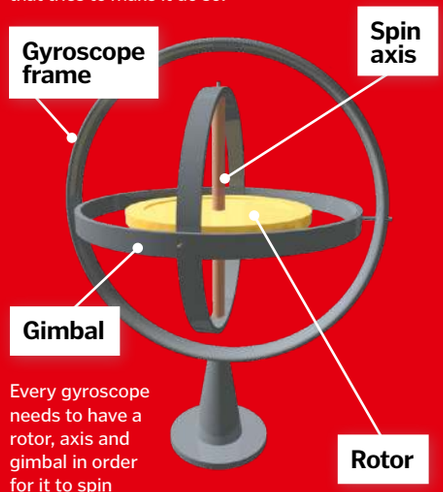
What else are gyroscopes used for?

Navigation

Have you ever wondered why planes and spacecrafts can judge their direction with such absolute precision? Gyroscopes are used in virtually all aviation and space technology in order to measure precise changes in orientation. When you try to change the direction of a spinning gyroscope this creates a force that instruments can detect with extreme precision.

Precision balance

Gyroscopes help items to balance far better once the wheel or rotor is spinning. A gyroscope has zero balance while its rotor wheel is stationary and will fall over when you try to balance it. But once the rotor wheel is set in motion the gyroscope comes alive, allowing it to perform all manner of what seem like gravity-defying tricks and movements. For example, robots use gyroscopes to help them balance. Internal gyroscopes sense changes in direction and counter this with an opposite force to keep robots upright. Once a gyroscope is spinning and facing in one direction, it doesn't like to change that direction and will 'fight' hard against anything that tries to make it do so.



Every gyroscope needs to have a rotor, axis and gimbal in order for it to spin

Wakeboarders use the Powerball® to strengthen their grip

13 CHEMISTRY LIFE HACKS

A little science knowledge goes a long way when it comes to solving these everyday problems

A common complaint in science classrooms is that nothing you learn in your school chemistry class will be useful in everyday life, but we've got 13 chemistry life hacks that prove otherwise. We'll show you how getting to grips with freezing points can cool your drink in record time, how electrolysis can clean your silver jewellery, and how understanding acids and bases can de-stink your fridge. We've got a trick for removing rust with an everyday acid, a way to use your knowledge of solubility to get a red wine stain out of your carpet, and a food chemistry hack for reviving stale cookies.

Chemistry explains what matter is made of, the properties it has, and how different molecules interact in the world around us. And understanding the chemistry behind common home conundrums will make your food taste better and save you a ton on expensive cleaning products and time.

HACK #1 Fix bitter coffee

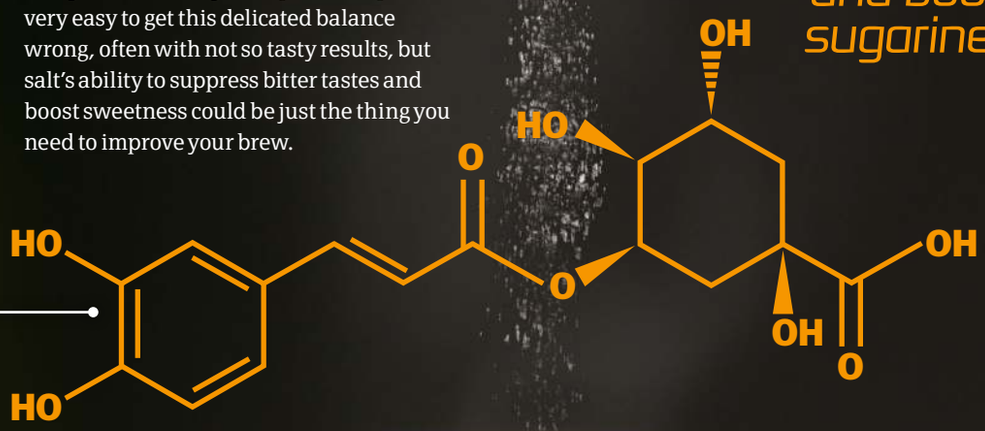
It's well known that salt makes food taste good, but in 1997, scientists found out why. In a study published in the journal *Nature*, they asked volunteers to drink a bitter urea drink with added sucrose for sweetness, or sodium acetate for saltiness. Sugar didn't improve the taste on its own, but salt did, and when the two were combined, the drink tasted even sweeter. It seems salt blocks bitterness and boosts sugariness.

Coffee contains many different bitter-tasting molecules, which contribute to its very distinctive flavour, but it takes a careful balance of temperature, brew time and ground size to get the perfect cup. It's very easy to get this delicated balance wrong, often with not so tasty results, but salt's ability to suppress bitter tastes and boost sweetness could be just the thing you need to improve your brew.

"Salt blocks bitterness and boosts sugariness"

Coffee chemistry

The smell and taste of coffee are the result of a complex mix of molecules



Bitter molecules
Coffee beans naturally contain chlorogenic acids, which break down into bitter quinolacetones, phenyl indanes and melanoidins when the beans are roasted. These are responsible for the flavour.

Brew time
The longer the coffee grounds are in contact with water, the more the bitter compounds enter the drink and the stronger it tastes.

Water temperature
The temperature of the water affects how well the bitter molecules are extracted from the coffee. Ideally, it should be between 90 and 96 degrees Celsius.

Grind size
The finer the grind, the more surface area is in contact with the water and the faster the bitter molecules will dissolve.

Salt
Adding salt counteracts the bitterness and increases sweetness. Minerals in hard water affect the taste too.

HACK #2 Remove rust with cola

Phosphoric acid is the sour ingredient that balances the sugary taste of the world's favourite fizzy drink, but it's got another use — it's an industrial-strength rust remover capable of transforming reddish iron (III) oxide into yellow-toned ferric phosphate. To repair a rusty object, simply cover it in cola and let the acid get to work. Not only will it help to remove the rust, the layer of iron phosphate will provide some rust proofing, protecting against future corrosion.


Iron reacts with oxygen in the presence of moisture, creating red-toned iron oxide

HACK #3 Check if eggs are fresh

Fresh eggs are full to the brim with yolk and white, but the shell is porous to allow the developing chick to breathe. Over time air leaks through the protective coating and a bubble starts to form. For a sure-fire way to tell if your eggs are fresh, simply put them in a bowl of water and see if they sink or swim.

The freshest eggs are best for frying or poaching because the yolk is round and the white is thick. These should sink to the bottom of the bowl and lie down horizontally on their side. Slightly older eggs are better for hard boiling because the white is thinner and they are easier to peel. These eggs will tip up on their edge, sitting upright in the water but not quite floating. The oldest eggs will rise to the top of the water. These are best thrown away as they are not really fit to eat.

Fresh or not?

How to quickly identify a good egg without having to crack the shell

"Egg shells are porous to allow developing chicks to breathe"

Cool your drink with salt

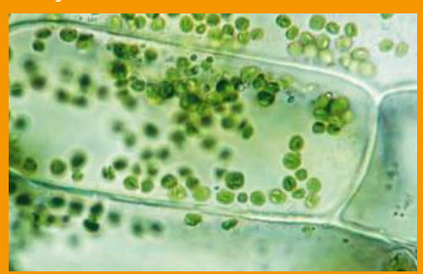
HACK #4 There's a layer of liquid water on the surface of ice, and when you add salt it dissolves into this layer. This dissolved salt slows down the rate at which water molecules can attach to the ice beneath but doesn't affect the rate at which molecules detach from the solid. The overall effect is more molecules detaching and becoming liquid, allowing the ice to melt without raising the temperature.

If you put a can into an ice bucket only parts of the surface touch the chilly solid, but add salt to the mix and the chilly liquid will completely surround your can, cooling it down much faster.

Gritters coat the road in salt to lower the freezing point of ice and snow

Keep your veg green

HACK #5 When you first plunge veggies into boiling water, air bubbles expand, making their green colour appear more intense, but over time the vibrant shade turns yellow. This is because a magnesium ion in the green pigment, chlorophyll, is swapped for hydrogen in the presence of acids released during cooking. To prevent this from happening, minimise cooking time, use lots of water to dilute the acid, and don't add vinegar or lemon until you're ready to eat.



Plant cells are stuffed with chloroplasts, which contain the green pigment chlorophyll

HACK #6 Ripen fruit with fruit

Ripe fruits like tomatoes and bananas give off ethylene, or ethene. This natural chemical is also known as 'fruit-ripening gas' and has been used for centuries to artificially speed up fruit ripening. The Egyptians made holes in figs to let the gas out, people in ancient China burnt incense to release ethylene, and modern transport vehicles pump the gas over fruit on their way to the supermarket to ensure it's ready to eat on arrival. To use this trick at home, just place an ethylene-producing fruit like a banana, fig, mango, nectarine or plum next to an unripe fruit and it'll be ready to eat in no time.

A favourite of the ancient Egyptians, figs encourage other fruits to ripen

Ripe bananas give off ethylene gas, which tells other fruits to ripen

Ripe
A ripened banana contains higher levels of antioxidants.

Unripe
High in resistant starch, unripe bananas are best eaten cooked or fried.

HACK #7 Thread needles with nail varnish

Poking a soft, frayed thread through the eye of a needle can be a challenge, but a bottle of nail varnish makes the job much easier. Nail varnish contains nitrocellulose suspended in a fast-evaporating solvent — when you apply a dab to the end of your thread, it rapidly forms a smooth film over the strands.

A coating of nail polish smoothes out fibre strands to make threading a needle easier

BICARB HACKS

Humble baking soda is all you need to solve these common household problems

Refresh tarnished silver

HACK #8

Silver can lose its lustre over time, becoming coated in a layer of black silver sulphide, but there's a chemistry trick to gently restore its shine. The first thing to do is line a bowl with aluminium foil and then add a spoon of baking powder, a pinch of salt and some hot water. The bicarbonate of soda will react with the foil, stripping away the layer of aluminium oxide on the surface, while the salt allows electrons to move between the foil and the silver, creating a small electrical current. The silver gains electrons and the aluminium loses them and, in the process, the sulphur transfers from your cutlery to the foil.

The black tarnish on old silverware is silver sulphide

Make bread without yeast

HACK #9

The bubbles that make bread dough light and airy are most often made by yeast, a single-celled organism that consumes sugar and produces carbon dioxide, but you can still make a decent loaf without it. Soda bread is a traditional quick bread with four key ingredients: flour, bicarbonate of soda, salt, and an acid like buttermilk, milk, yogurt or cream of tartar. The soda reacts with the acid to make carbon dioxide, allowing the bread to rise. But be careful with the proportions; the bread will collapse if the bubbles become too big, and too much bicarbonate of soda can make the mix taste soapy.

Bicarbonate of soda can replace yeast to make dense, rustic soda bread

Banish fridge odours

HACK #10

Bicarbonate of soda has the chemical formula $NaHCO_3$, and it's got some special properties. It is amphoteric, which means it can react with both acids and bases, and this makes it a great DIY fridge deodouriser. Lots of bad food smells are caused by acids and alkalines produced as food starts to go off; sour milk contains lactic acid, bad meat contains rancid fatty acids, and rotten fish contains alkaline trimethylamine oxide. When bicarbonate of soda reacts with these, it forms a sodium salt, water and carbon dioxide, neutralising the odour. An open box inside the fridge door should help to keep bad smells at bay.

Bicarbonate of soda can neutralise bad smells by reacting with acids and alkalis

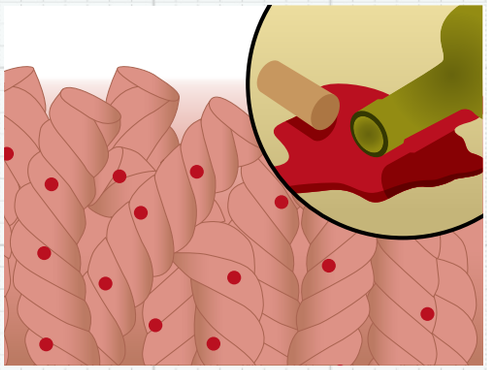
HACK #11 Remove wine stains with vodka

The distinctive colour of red wine is created by pigments called anthocyanins and pyranoanthocyanins, which are formed when anthocyanins interact with molecules made by alcohol-producing yeasts. Their chemical structure makes them a little bit hydrophobic ('water hating') and a little bit hydrophilic ('water loving'), meaning that they dissolve in both organic solvents, like alcohol, and aqueous solvents, like water.

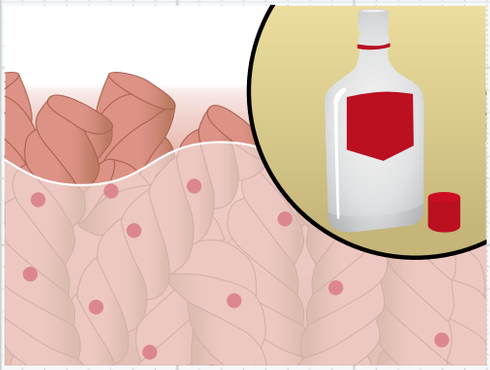
White wine is often used to remove red wine stains because it contains a mix of alcohol and water, helping to capture the pigment molecules and pull them out of the fabric, but a better option to quickly remove a stain is to use something stronger. Clear spirits like vodka, white rum or gin contain a higher percentage of alcohol, dissolving the pigment molecules even more effectively. Just keep dabbing at the stain and adding more alcohol until the colour begins to fade away.

Carpet stain chemistry

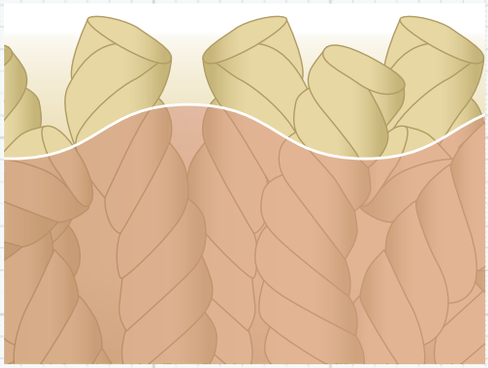
How to dissolve red wine pigments before they stain your fabrics



1 Stain
The anthocyanin pigment molecules in red wine get stuck between carpet fibres, staining the fabric pink.



2 Add alcohol
The mix of water and alcohol in a high-proof spirit like gin dissolves the pigment molecules.



3 Dab
The dissolved pigment can be removed from the carpet by dabbing at the stain with a cloth.

4 Rinse
Rinse any alcohol residue away with water and your carpet will be as good as new.

"Vodka, white rum or gin will dissolve red wine pigment molecules more effectively"

Descale your kettle with vinegar

HACK #12

Hard water contains dissolved calcium hydrogencarbonate, which breaks down into insoluble calcium carbonate, also known as limescale, when it's heated. To get rid of it, mix one part vinegar or lemon juice with three parts water and boil the kettle, then let the hot mixture sit overnight. The acid will react with the limescale, forming soluble calcium salts that can be tipped away in the morning.

A scanning electron microscope image showing crystals of limescale inside a kettle

Soften cookies with bread

HACK #13

Bread, cake and cookies contain moisture, which transforms starch from crystals into a disorganised gel, but as moisture moves away from the starch, they go hard and stale. All you need to do to refresh baked goods is restore that moisture. Simply put your hard cookie in a bag with a piece of fresh bread and it should soften up in no time.

The starch inside cookies turns to orderly crystals as they dry out

MRSA, a Staphylococcus aureus strain, is resistant to many antibiotics

The antibiotic apocalypse

Are we heading towards a future where infections are immune to treatment?

We have a major problem. Since the dawn of humanity, we have been locked in a battle with microscopic organisms, and just when we thought we were starting to win, they're fighting back.

Bacteria cause some of the most devastating human diseases, from typhoid fever to tuberculosis, and until the 1920s we were utterly defenceless. But when Alexander Fleming ushered in the age of the antibiotic with his discovery of penicillin, we suddenly had a powerful weapon.

Antibiotics work by stopping bacteria from dividing or by killing them outright. Thanks to them we can treat infections that were once fatal, we can perform complex surgery, and we can mass-produce food on an unprecedented scale. But we have used them and used them and used them, and the bacteria have started to learn, with dangerous consequences.

These little organisms can replicate in a matter of hours, and each time they do they make tiny, accidental tweaks to their genetic code. Some tweaks aren't useful, but very occasionally a mistake is made that helps one bacterium to outlast an onslaught of antibiotics for just a little longer than their neighbours.

When the course of antibiotics are finished, and all of the vulnerable bacteria are dead, this slightly stronger individual can carry on dividing, making a new colony that are all a little bit better at avoiding the effects of the drugs. And if this happens time after time you soon have a superbug on your hands.

Worse still, bacteria are able to share useful genes with their neighbours. And not just members of their own species. They carry useful snippets of genetic code in little rings of DNA called plasmids, which they can swap like trading cards, passing resistance on to others around them.

Using these tactics several strains of bacteria are now able to evade almost all of the antibiotics in our arsenal. We're in the middle of a microscopic arms race, and the future of medicine is hanging in the balance.

Antibiotics are used everywhere, from hospitals to intensive farms

What needs to be done?

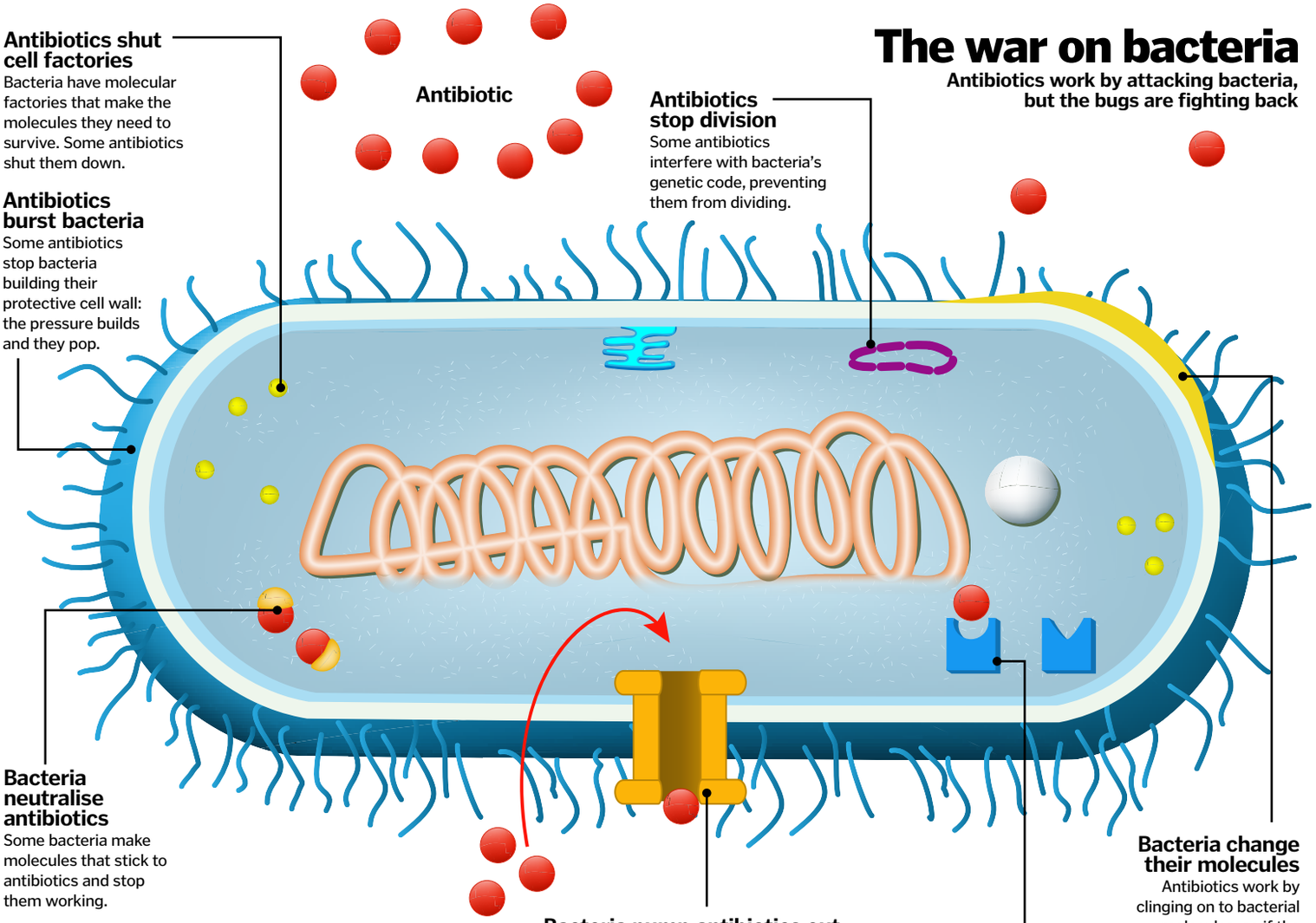
Ensuring that effective antibiotics are available for future generations is a mammoth task. We need to stop giving bacteria the opportunity to see our best treatments.

Vets and doctors are being urged to only use antibiotics if absolutely necessary and to test their patients beforehand to check that the treatment will definitely work to kill the infection. Patients are being asked to always finish their full course of antibiotics, even if they feel better, to ensure that any lurking bacteria are cleared up. Farmers are being encouraged to keep their livestock clean and vaccinated rather than use antibiotics to control disease.

Governments and development organisations are under pressure to regulate and monitor antibiotic use and to make sure people have access to the right antibiotics. And the medical research community is racing to find new drugs to fight resistant strains. Rather than throw antibiotics at any infection, we need to choose our battles more carefully.

The war on bacteria

Antibiotics work by attacking bacteria, but the bugs are fighting back



Antibiotics shut cell factories
Bacteria have molecular factories that make the molecules they need to survive. Some antibiotics shut them down.

Antibiotics burst bacteria
Some antibiotics stop bacteria building their protective cell wall: the pressure builds and they pop.

Antibiotics stop division
Some antibiotics interfere with bacteria's genetic code, preventing them from dividing.

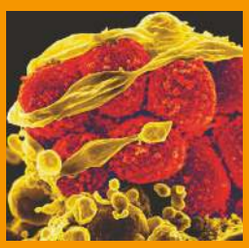
Bacteria neutralise antibiotics
Some bacteria make molecules that stick to antibiotics and stop them working.

Bacteria pump antibiotics out
If antibiotics do get inside bacteria, some are able to pump them straight out again.

Bacteria block antibiotic entry
Some bacteria have developed ways to stop antibiotics from getting through their cell walls.

Bacteria change their molecules
Antibiotics work by clinging on to bacterial molecules, so if the bacteria can change their shape they can sometimes escape.

Superbug lineup



MRSA
Methicillin-Resistant Staphylococcus aureus (MRSA) is the most infamous of all superbugs. Regular Staphylococcus aureus is a common type of bacteria, normally found harmlessly on the skin. This bug first started resisting the effects of antibiotics as far back as the 1950s, however, and MRSA itself first appeared in 1962.

VRE
Vancomycin-resistant Enterococcus (VRE) is immune to the effects of one of our most powerful antibiotics. Vancomycin is usually reserved for the most serious of infections, including meningitis and MRSA. These superbugs were first spotted in the 1980s and have proven very good at developing resistance to any new antibiotics thrown at them.

MDR-TB
Multi-Drug-Resistant Mycobacterium tuberculosis (MDR-TB) does not respond to the two most powerful anti-tuberculosis drugs currently available — rifampicin and isoniazid. Normal treatment for TB involves a combination of antibiotics taken for six months, but if the drugs are given alone or stopped too soon, resistance can develop.

KPC
Klebsiella pneumoniae carbapenemase-producing bacteria (KPC) are a relatively new problem, first identified in the US in the early 2000s. They are very good at resisting treatment and also produce an enzyme that allows them to break down carbapenem, a powerful antibiotic that's one of our last lines of defence.

Learn more

Arm yourself with information
Knowledge is the most powerful weapon we have against an antibiotic apocalypse. Here are two top places to learn more:

- **The World Health Organisation**
www.who.int
Working in over 150 countries, the World Health Organisation are leading the fight against antibiotic resistance. Their social media accounts are a great place for bite-sized news and updates.

- **Bugs and Drugs**
www.antibioticresistance.org.uk
With funding from the British Government's Department of Health, the National Electronic Library of Infection have made a one-stop hub of information about antibiotic resistance.

How does superglue work?

Find out what makes superglue so super strong

Superglue doesn't stick to the inside of its bottle because water molecules are needed for a chemical reaction to occur

We all know that superglue is really sticky, but did you know that just 6.5 square centimetres of superglue can hold over a ton! In fact, superglue is so robust we can even use it to heal wounds like fractured skulls. But what gives it these superhero powers?

Superglue relies on the presence of water molecules, which is why it doesn't stick to the inside of the bottle. It is made from cyanoacrylate, a type of acrylic resin. Cyanoacrylate contains its own hardening blend of chemicals, but a weak acid is also added to the superglue mix that acts as an inhibitor to keep the molecules separated. This is why superglue is a liquid inside the tube.

When exposed to water vapour molecules in the air, the hydroxyl ions cause the acid to dissolve, triggering a reaction. This reaction causes the molecules to rapidly heat, fuse together and quickly cool, hardening between the two surfaces and bonding them together.

The sound of the ocean in a shell is really just the sound of the environment around you 'caught' in the shell

Seashell resonance

Can you really hear the ocean in a shell?

Legend has it that if you hold a large shell up to your ear you can hear the waves of the ocean no matter how far away from it you are. Sadly, this is only a myth. So what noise can you hear when you do this?

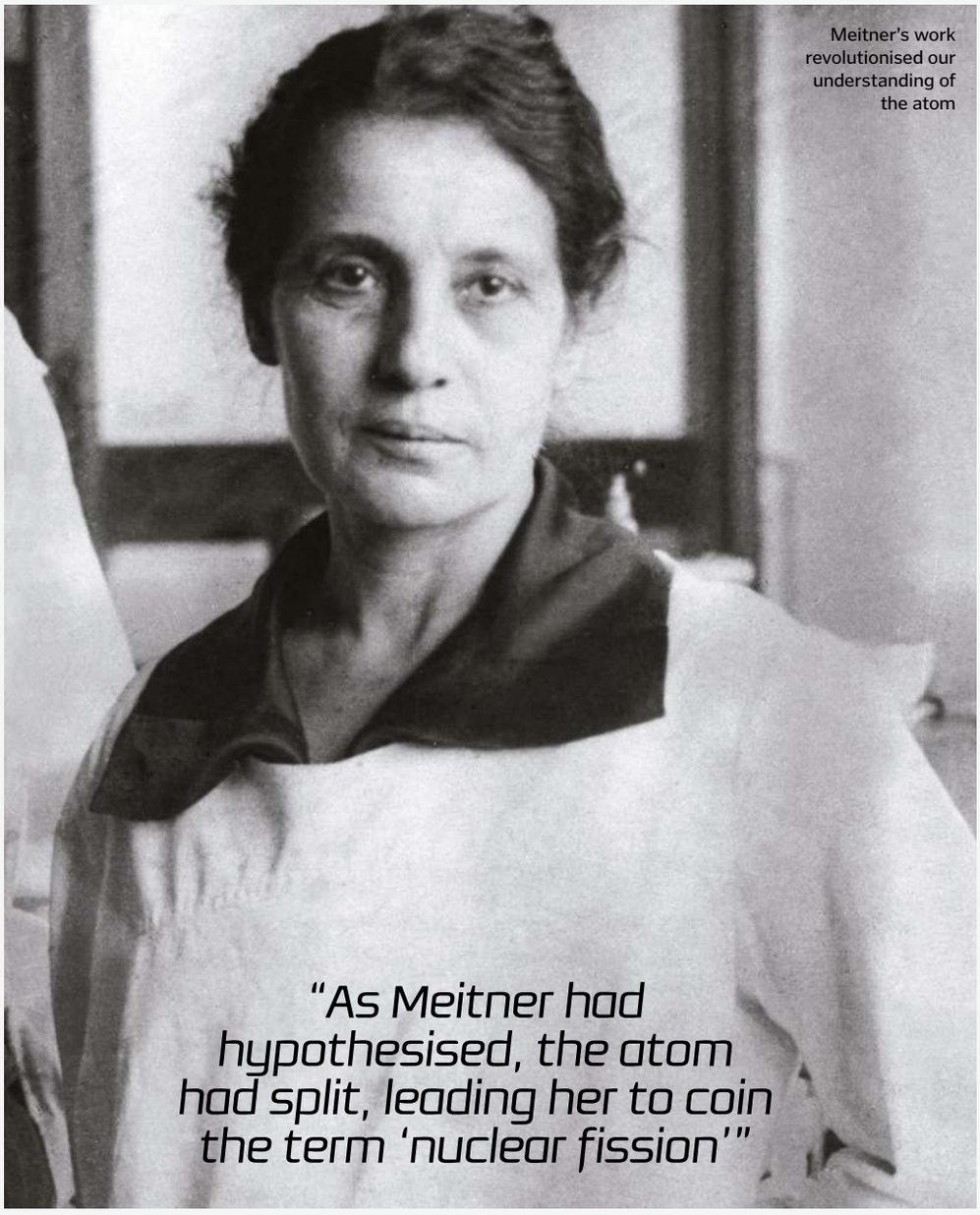
There have been a few tried-and-tested theories. One of the most popular beliefs is that it is the sound of your blood moving around your body. However, this is easily disproved as the sound doesn't intensify after exercise as would be expected if this were in fact the case.

There had been suggestions that the sound is created by air flowing around the shell, but this was debunked by researchers who found the sound did not occur under test conditions in a soundproof room with a current of air.

This leaves the most plausible explanation being that the sound you are hearing is caused as the seashell captures ambient noise from the environment. The sound waves bounce around the cavity inside the shell, resonating inside and creating a noise. And you don't even need a seashell to try this at home. Just use a plastic cup or your hand, and cup it over your ear to hear a similar 'ocean' noise.

Lise Meitner

An innovative physicist and the mother of nuclear fission



Meitner's work revolutionised our understanding of the atom

"As Meitner had hypothesised, the atom had split, leading her to coin the term 'nuclear fission'"

Born in Vienna, Austria, in 1878, Lise Meitner was the third of eight children. During her time at public school Meitner gained a growing interest in physics and maths. By 1901 Meitner had passed her qualifying exams and attended the University of Vienna, where she met professor Franz Exner. As a respected physicist, Exner introduced her into the then growing world of radioactivity.

After completing her doctoral degree in 1906, Meitner spent the next year teaching at an all girls' school while continuing her research, focusing on alpha and beta radiation absorption. Moving to Berlin in 1907, Meitner joined the Chemistry Institute at the University of Berlin, where she met her future collaborator, chemist Otto Hahn. As an unpaid guest, Meitner was given a small basement room to set up her laboratory. A year later she was made a scientific associate, allowing her and colleague Hahn to combine academic disciplines and expand their lab above ground. It wasn't until 1912 that Meitner got her first paid position of assistant.

The discovery of the neutron by physicist James Chadwick in 1932 created a buzz in the research of neutron irradiation/bombardment of different elements. Working with radiation, Meitner and Hahn naturally wanted to follow suit and set up a series of experiments irradiating uranium. At the same time, Nazi Germany was on the cusp of starting WWII. As a Jewish woman, Meitner feared for her life and fled from Berlin to Stockholm in 1938. In her absence, Hahn and his assistant Fritz Strassmann continued their work with uranium.

The trio collectively carried on their research, communicating predominately via letter. During Meitner's absence Hahn was faced with an unexpected result. Writing to Meitner, Hahn informed her he had discovered the presence of the element barium after bombarding uranium with neutrons. Taking a mathematical approach, Meitner concluded the uranium atom had become unstable and ruptured, releasing the unexpected barium and a vast amount of energy. After further repeats Meitner's hypothesis was

A life's work

The life of Lise Meitner and her greatest achievements as a trailblazing physicist

1878
Lise Meitner is born in Vienna, Austria, into a Jewish family.

1901
She joins the University of Vienna, where she discovers a fondness for physics and mathematics.

1906
Meitner is awarded her doctoral degree for her paper on the conduction of heat in inhomogeneous solids.

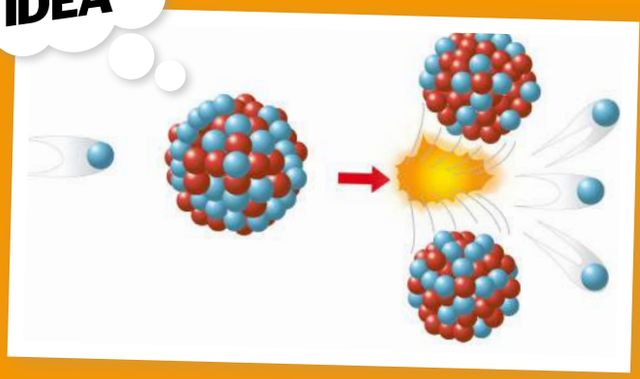
1907
Meitner joins forces with chemist Otto Hahn at the University of Berlin in the Chemistry Institute.

1919
After observing nuclear decay, she and Hahn discover a new element: protactinium.

THE BIG IDEA

The discovery of nuclear fission

Uranium is the heaviest naturally occurring element on Earth and it was Meitner and Hahn's intension to fire neutrons at the element to increase its mass. However, rather than grow the atom, they had split it. When a neutron is fired at uranium-235, it causes the atom to become unstable and divide into the smaller elements barium and krypton. At the same time, heat energy is released, along with three new neutrons. In the presence of more uranium-235 these new neutrons will continue to split other uranium atoms, causing a powerful chain reaction.



Neutrons released by nuclear fission cause a chain reaction, generating a vast amount of energy

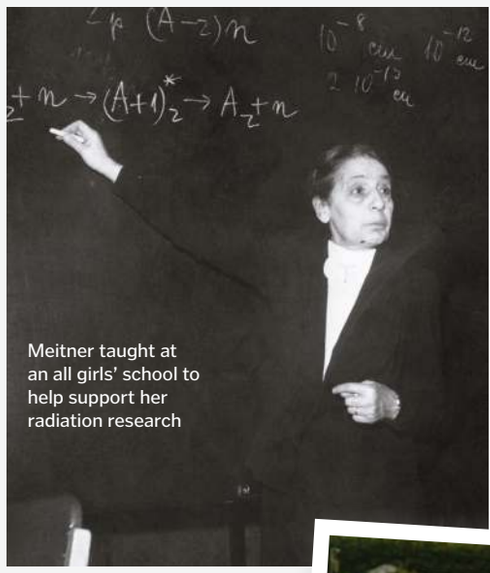
proved correct — the atom had split, leading her to coin the term 'nuclear fission'.

In 1939 Hahn and Strassmann published the trio's finding and announced they had split the atom by nuclear fission, but Meitner was not listed as an author. As the news broke of nuclear fission, especially the high levels of energy it emits, the potential for a nuclear weapon became clear. Meitner was therefore asked to contribute to the development of the atomic bomb in the Manhattan Project. She refused, stating, "I will have nothing to do with a bomb".

Hahn went on to win the Nobel Prize for the discovery of nuclear fission in 1944, whereas Meitner wasn't recognised until 1966, when all three contributors won the prestigious Enrico Fermi Award. Meitner passed away in 1968 in Cambridge, England aged 86.

Meitner and Hahn combined their work in physics and chemistry for 30 years

The experiment equipment used to discover nuclear fission now sits on exhibition in the Deutsches Museum in Munich, Germany



Meitner taught at an all girls' school to help support her radiation research

5 THINGS TO KNOW ABOUT... LISE MEITNER

1
She was the first female professor in Germany
Qualifying to teach in a university in 1926, Meitner was the first woman to be employed as a professor of physics at the University of Berlin.

2
She was the second woman with a doctorate in Austria
Women entering into further education were rare during the 19th century due to financial and political restraints.

3
Albert Einstein was a fan
Calling her "our Madam Curie", Einstein praised Meitner when the Nobel Prize Committee overlooked her.

4
There's an institute and element named after her
The Hahn-Meitner Institute was set up in 1959 to explore nuclear research. Physicists Peter Armbruster and Gottfried Münzenberg created 'meitnerium' in 1982 after bombarding the element bismuth with iron ions.

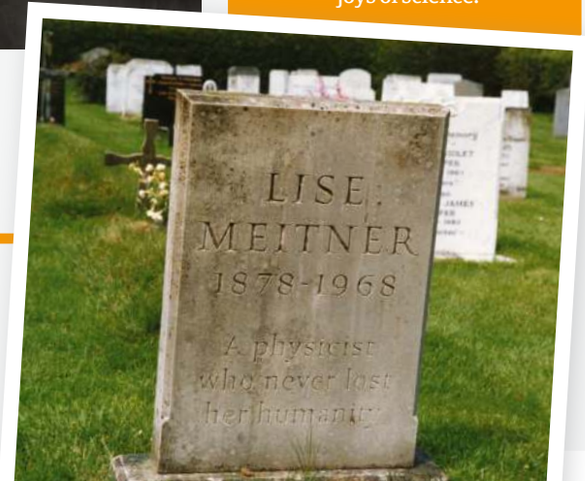
5
She never returned to Germany
Meitner travelled during her later years of life. She spent her time lecturing and encouraging female students to explore the joys of science.

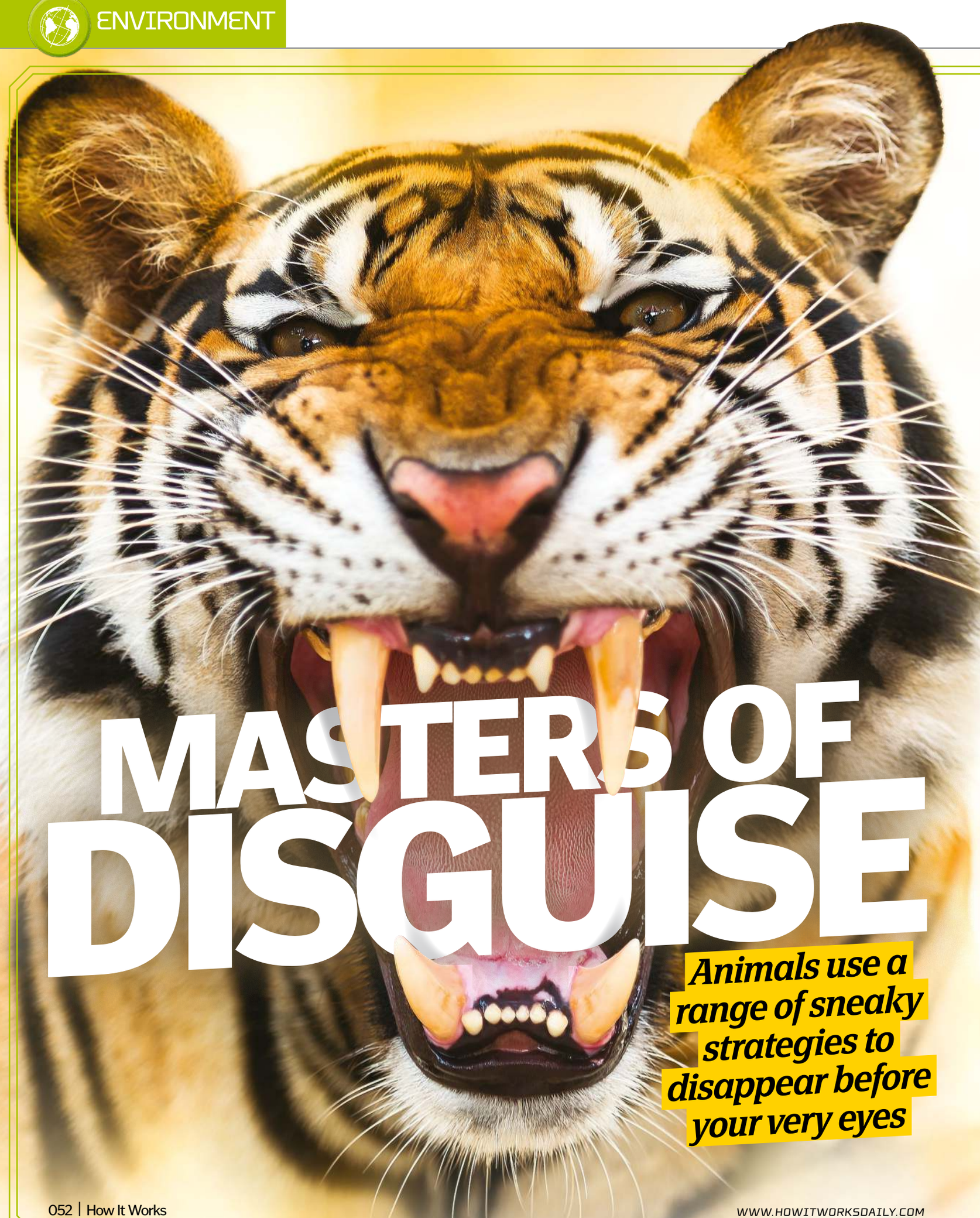
1938
Meitner, along with Hahn and chemist Fritz Stresemann, split a uranium atom: nuclear fission is discovered.

1939
Otto Hahn and Fritz Strassmann publish the findings of the uranium experiments, but Meitner is not listed as an author.

1966
Meitner, Hahn and Strassmann are awarded the prestigious Enrico Fermi Award, recognising their discovery as a team effort.

1968
Meitner dies after declining health and a series of small strokes. Her gravestone reads, 'A physicist who never lost her humanity'.





MASTERS OF DISGUISE

Animals use a range of sneaky strategies to disappear before your very eyes

True camouflage goes far beyond patterned clothing and slathering on a bit of face paint. Millions of years of evolution have sculpted the natural world and everything that inhabits it. An enormous number of animal species have developed some kind of mechanism to hide from their enemies, even at point-blank range.

Being the same colour as the surroundings is one method to avoid detection. This is known as concealing colouration. Polar bears blend in with the icy backdrop, and green chameleons are almost indistinguishable among leafy trees. It's no coincidence that many animals share their colour scheme with their environment, however. During evolution, conspicuous predators would have struggled to find food, and prey species that stuck out would have been snapped up quickly. An early death means an animal isn't able to pass its genes on to the next generation. Those that survive long enough to breed give rise to offspring that have the same genetic strengths. This is how natural selection works, and species tend to get stronger with each new generation.

Several icy animals lose their white fur once the snow has melted. Arctic foxes are Iceland's only native land mammal and are perfectly camouflaged against the dark, volcanic landscape during the summer. However, as the planet has undergone a lot of change over the past few centuries, some animal camouflage is out of date. Most seal pups are pure white to blend in with the Arctic snow in which they evolved. However, while some species remain in polar regions, many have migrated away from the frost but still retain that white baby fur.

If fitting in isn't quite your thing, maybe disruptive colouration is for you. High contrast patterns make it difficult for the eye to detect an animal's outline, and most experts agree that this is a better form of camouflage than matching the background. Zebras use their bold stripes to confuse predators in several different ways. A lion may misjudge which direction the zebra is facing, giving the banded horse a split-second advantage if the big cat gets it wrong. Alternatively, a hunter observing a group may have difficulty judging where one animal ends and the next begins. This could result in a poorly aimed chomp from which the zebras can flee unharmed to safety.

Predators use this strategy too. Hyenas have dark spots to cloak their shape from vigilant prey. Animals that are likely to be hunted have been hard-wired to look out for signs of danger over millions of years, but patterned predators like hyenas or African wild dogs are able to get close enough to their prey without detection to snatch a single animal from a herd.

"Mimicry is the sincerest form of flattery...many animals pretend to be something they're not"

Angular Asian horned toads hide among leaf litter using concealing colouration

Some animals only rely on their pattern in infancy. Baby tapirs bear bright, cream-coloured stripes along the body and down each limb. The fully grown monochrome mother doesn't need camouflage as she has a much better chance of defending herself from one of the species' few natural predators than a new-born calf would. As a result the stripes fade once the young tapir reaches a safer size.

Mimicry is the sincerest form of flattery, and a huge range of animals have found success by pretending to be something they are not. An

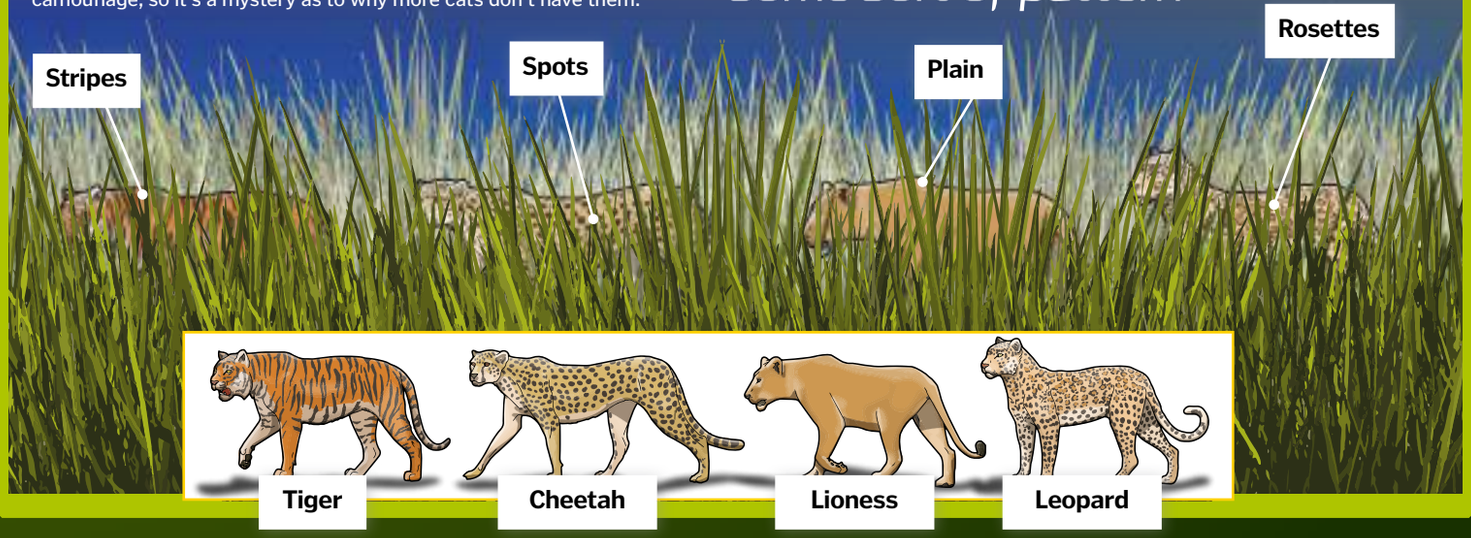
Spots vs stripes

There are around 40 species of wild cat, each of which has to hunt to find food. In general, cats that live in open habitats are more likely to be plain, and most felines that live in dense habitats have some sort of pattern. However, there are exceptions to this rule, like the spotted cheetah that lives out on the savannah, and the plain bay cat that spends its life in the forest.

Round markings are the most common for big cats and these can be in the form of solid spots or dappled rosettes. Tigers are the only cats to have regular vertical stripes, which may suggest that spots are better camouflage than straight lines. But there's no definite answer on this yet. Researchers agree that vertical stripes are extremely effective camouflage, so it's a mystery as to why more cats don't have them.

"Cats that live in open habitats are more likely to be plain, and most felines that live in dense habitats have some sort of pattern"

WHICH CAT IS HARDEST TO SEE?
VOTE IN OUR POLL ON SOCIAL MEDIA



obvious example is the hoverfly, which has black and yellow bands that resemble those of wasps. Early flies that had warning stripes may have been avoided by predators for fear of the sting. Thus, hoverflies have survived over the years by hiding in plain sight by accident.

Then there is Batesian mimicry, where animals find success in copying a more dangerous or less palatable species. Harmless scarlet kingsnakes mimic their venomous coral snake cousins to avoid being picked off by a predator. Delicious viceroy butterflies masquerade as their foul-tasting monarch neighbours to deter bird attacks. Female mocker swallowtail butterflies can take on one of many morphs that look like local toxic butterflies. Males don't have this ability, and while nobody knows why, it has been suggested that males and females wouldn't recognise one another if they were both disguised as other species.

But mimics don't just copy other animals. Leaf-tailed geckos and orchid mantises pose as plant parts to get close to their insect prey. On the other side of the same coin, plant mimics like the bizarre potoo can fool a ravenous meat-eater into leaving the scene empty-handed. These birds pose on trees or atop wooden poles and puff up their feathers to match the circumference of the perch. A passing carnivore would struggle to determine what's tree and what's tasty bird meat.

Some animals use disguise to survive, meaning they adopt a different appearance to conceal themselves. 300 different spider species imitate ants by pretending their front two legs are actually antennae. They wave these limbs around in a similar fashion to an exploring insect and even adopt a meandering, ant-like gait to gain the trust of their future food.

Other species physically cover up their bodies to shield themselves from the world. Decorator crabs have a shell covered with Velcro-like barbs. The crustacean attaches bits of anemone and sponge to its back to blend in with ocean flora, and these fashion statements can even attract marine life to take up residence on the crab's back. Some decorator crabs take this even further by carefully selecting toxic algae to wear, so even if it does get recognised it has a back-up plan. Like most other crabs, the animal moves on when its body gets too large for the brittle

The patient orchid mantis looks so much like a flower that insects approach without a second thought

Almost invisible among the snow, the Arctic fox's eyes and nose are all that give it away

"Assassin bugs sheathe their bodies with insect carcasses to gain the trust of passing prey"

Pygmy seahorses pretend to be coral polyps by anchoring themselves by the tail

Researchers have likened cuttlefish skin to HD TV screens, able to emulate a wide array of colours, patterns and textures

Extreme body modification

Cuttlefish and their relatives can take on a new identity at will

Texture transformation
Circular bands of muscles embedded in the skin can force flesh to take on a new shape. The spiky flesh mirrors the texture of rock, coral or other naturally occurring ocean structures.

Long lens
Cuttlefish eyes focus back and forth like a camera lens and are able to perceive edges of objects, judge distance and identify background objects to pose as.

Chromatophores
The skin surface contains sacs of pigment called chromatophores. These can be contracted and relaxed to concentrate or spread out the inky fluid to darken or lighten the skin.

Colour blind
Despite their miraculous colour-changing ability, cephalopods like cuttlefish and octopuses are unable to detect colour in the same way as humans can.

Iridophores
Iridophores are reflective plates of protein that can change the way light reflects off the skin. This can make the skin appear brightly coloured.

Arms up
The tentacles can be moved and held in place to increase the cuttlefish's camouflage. Raising or splaying the arms changes the animal's shape.

Leucophores
These flattened, elongated, reflective cells are found in the skin of many shallow-water octopods, including some cuttlefish and squid species.

shell. A decorator crab will picks its ornaments from its old shell and transfers them over to its new carapace.

Parrotfish make themselves a mucous sac in which to sleep to disguise themselves from predators. But this works the other way around too, with some hunting animals able to hide their true identity from unsuspecting prey. Assassin bugs sheathe their bodies with debris or even insect carcasses to gain the trust of passing prey. As the name suggests, these animals are effective killers and a bite can leave a human in agony for several months.

Then there are the camouflaged critters that have to get well and truly creative with their cloaking ability in order to survive. Caterpillars of the Zulu blue and Roodepoort copper butterflies live among ant colonies. While they don't look anything like their wingless roommates, the butterflies-to-be produce the same chemicals emitted by ant larvae. This triggers a parental care response from the surrounding ants to trick them into approaching, at which point they can be gobbled down by the very hungry caterpillars.

Underwing and tiger moths hoodwink bats by creating phantom sounds. Their soft insect bodies absorb echolocation calls from hunting bats, and the moths produce noises that mimic distant echoes of the bat's sonar. While a human would easily be able to tell the difference between a bat and a moth, the flitting mammals rely so strongly on sound that they struggle to tell which echo is genuine.

As for the reptile world, deadly puff adders can evade detection by sniffer dogs by suppressing their own scent, a vital skill (known as chemical crypsis) when trying to avoid scent-reliant predators like mongooses and meerkats. How these adders remain fragrance free still baffles scientists. The snakes could have an extremely low metabolism, breathe at minimum frequency or even hold off on breathing when sleep. That might seem extreme, but puff adders only have a 40 per cent chance of survival each year. They do everything in their power to live on and reproduce, and maybe holding their breath all night is a small price to pay to live another day.

Assassin bugs craft 'backpacks' from their leftovers to appear harmless to prey

Invisible underwater

Meet the masters of oceanic hide-and-seek

Plaice
Within the first six weeks of life the plaice's left eye travels to the opposite side of the body, allowing the fish to watch out while it lies camouflaged.

Humpback whale
Its white belly blends in with the light sky and its black back is camouflaged against the dark seabed, leaving prey no chance of escape.

Leafy sea dragon
The protrusions that grow all over its body make the seahorse almost undetectable among its weedy habitat.

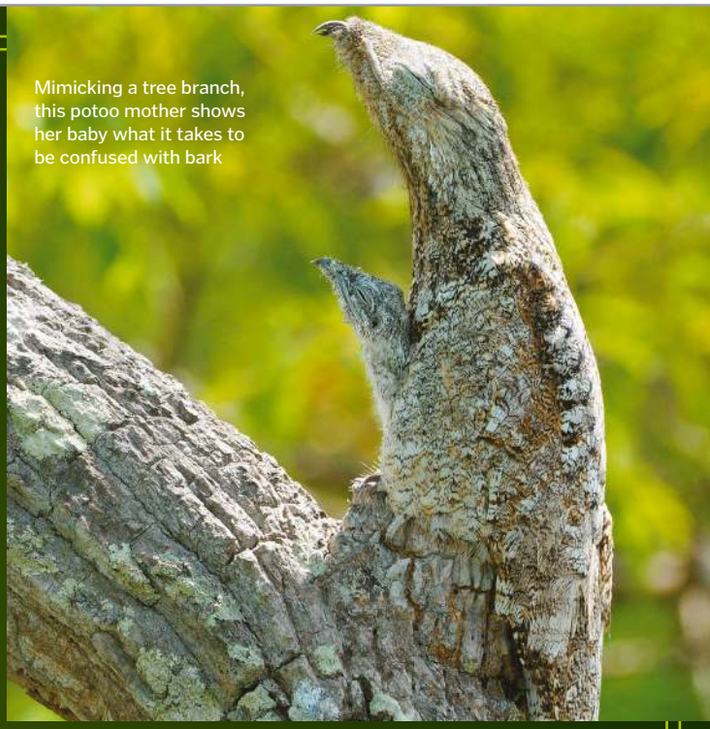
Mimic octopus
This animal copies the shape, colour and texture of deadly ocean animals like sea snakes and cone snails to intimidate its predators.

Fangtooth
Red light struggles to penetrate beyond 30 metres of the sea, and the red skin deep-water fish is darker than black beneath the waves.

Hourglass dolphin
The zebras of the ocean use disruptive colouration to create a wall of black and white that confuses predators.

Garden eel
These tiny fish plant themselves in sand and sway in the swell to disguise themselves as sea grass.

The decorator crab wanders the sea bed in a costume made from other marine life



Mimicking a tree branch, this potoo mother shows her baby what it takes to be confused with bark

"Patterned predators like hyenas are able to get close enough to their prey without detection"

The pale peppered moth (left) and its melanistic variant (right) are an example of natural selection

Evolution in action

One moth was able to adapt to the increase in air pollution during the Industrial Revolution at lightning speed. The peppered moth is a cream-winged night flier that can camouflage on lichen-covered tree trunks. It was discovered in 1758, but by 1811 everything had changed for the species.

As soot sprinkled over British cities, a new melanistic morph of the moth emerged. Its black body blended excellently with the freshly polluted surroundings that saw lichen fall from the trees. The light-coloured specimens were subject to predation by birds, while the dark moths were safely hidden from their avian oppressors. By 1895, up to 98 per cent of inner city peppered moths were black.

However, the cream costume has made a comeback since the early 1960s, with 50 to 90 per cent of moths wearing their signature colour.

Wildflower meadows

Discover the wild side of meadows and how you can make your own

Wildflower meadows, though vibrant and beautiful, play a vital role in maintaining pollinator populations, increasing biodiversity and providing habitats.

Whether it's the delicate foxglove or the humble cow parsley, wildflowers help support the 1,500 species of pollinator in the UK, offering food and shelter for insect pollinators such as bees and butterflies. And the more diverse a meadow's wildflower species is, the larger the diversity of pollinators that visit them, also helping to maintain insectivore populations.

Ecologically productive as they may be, these types of meadows typically grow in unproductive soil. Soils that are shallow, poor at holding water or acidic are categorised as unproductive. Grass species in particular can dominate a meadow with productive soils, out competing wildflowers such as bluebells. Yet despite this, wildflowers have adapted to thrive in these harsher conditions to keep the competition at bay.

However, these flower-rich fields have been declining dramatically. Around 97 per cent of UK wildflower meadows have been lost since the 1930s, occupying only one per cent of the UK's land area. This is a result of agricultural progress and land development. The introductions of livestock farming and herbicides have contributed to the removal of wildflower meadows, while the use of fertilisers has allowed surrounding soil to become more productive, meaning dominant grass species can threaten wildflowers. The development of roads and residential homes has also played a part in this concerning decline.

Ecological charities and organisations such as Plantlife and Kew Gardens campaign to reclaim wildflower meadows in the UK. From protecting wildflower roadside verges to making our gardens more 'wild', these efforts aim to support the declining pollinator populations.

Insects contribute to the majority of the pollination of wildflower meadows

Wildflowers act as a habitat for a range of species, including the harvest mouse

"97 per cent of UK wildflower meadows have been lost since the 1930s"

Make your own meadow

Here are seven steps to help you grow your own wildflower meadow:

1 The right space
Use a section of lawn or an old flowerbed, the bigger the better.

2 Digging up
Reduce the quality of your soil by removing the topsoil (around 15 centimetres) to rid the soil of any fertilisers.

3 Turning over
Dig and turn the remaining soil until it is fine.

4 An autumnal affair
The best time to sow wildflower seeds is during the autumn season.

5 Spotting your seeds
Use a pale coloured sand to top off the turned soil, but don't use builder's sand. This will allow you to see where you have sown your wildflower mix.

6 Use your feet
Don't rake or cover the seeds with soil — simply tread them into the ground so they come into contact with the soil.

7 A midsummer trim
Once your wildflower meadow has started to bloom don't mow it until midsummer.

Fata Morgana

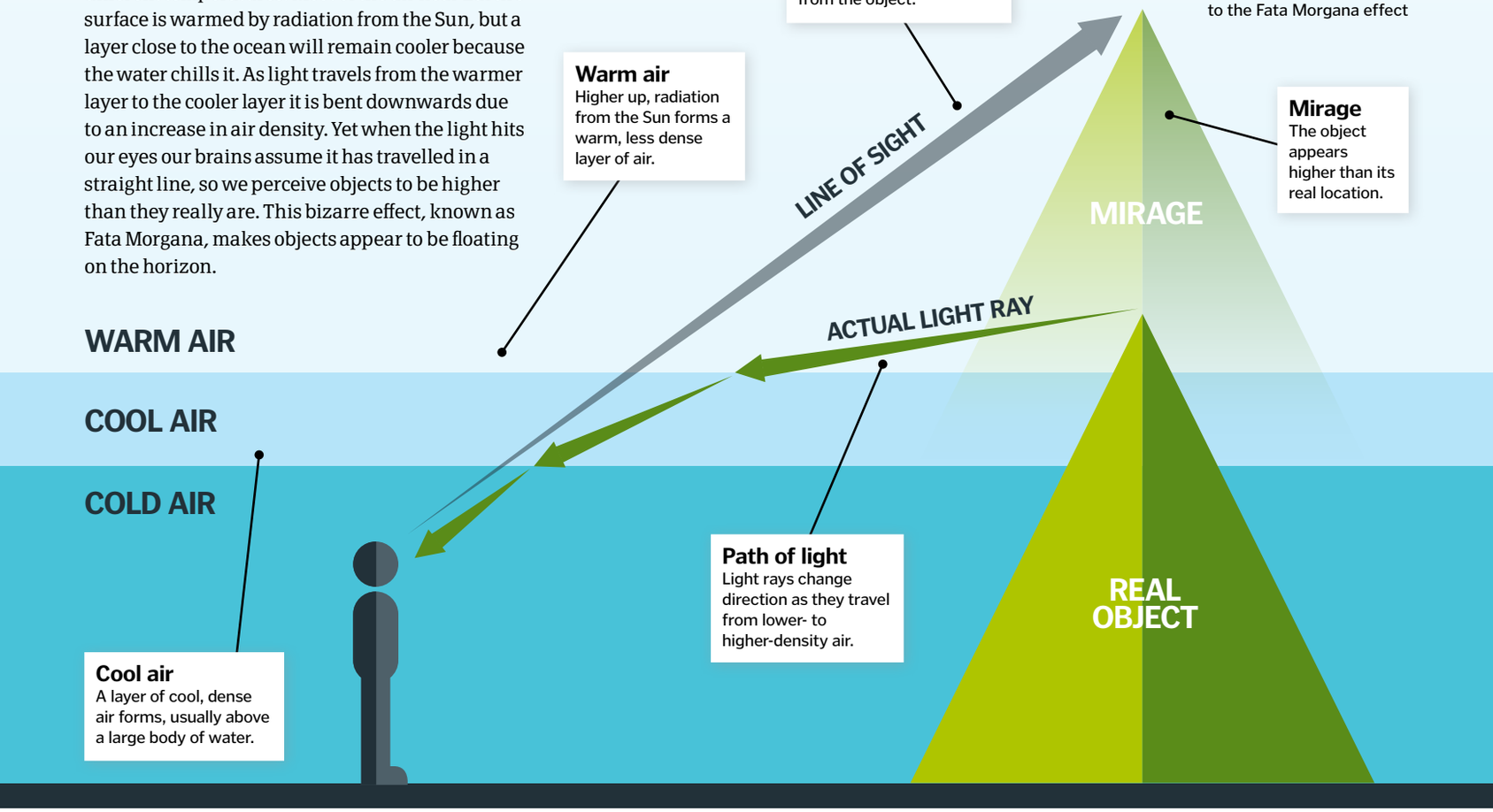
The optical illusion that makes objects hover above the horizon

The horizon is normally a reliable divider between sea and sky, but when atmospheric conditions are just right this boundary can seem blurred. Near the surface of the ocean, layers of air can form that are at different temperatures. Most of the air near Earth's surface is warmed by radiation from the Sun, but a layer close to the ocean will remain cooler because the water chills it. As light travels from the warmer layer to the cooler layer it is bent downwards due to an increase in air density. Yet when the light hits our eyes our brains assume it has travelled in a straight line, so we perceive objects to be higher than they really are. This bizarre effect, known as Fata Morgana, makes objects appear to be floating on the horizon.

A lighthouse appears to float above the water due to the Fata Morgana effect

Making a mirage

How our brains are tricked by the bending of light



Pig tails

Why do domestic pigs have curly tails?

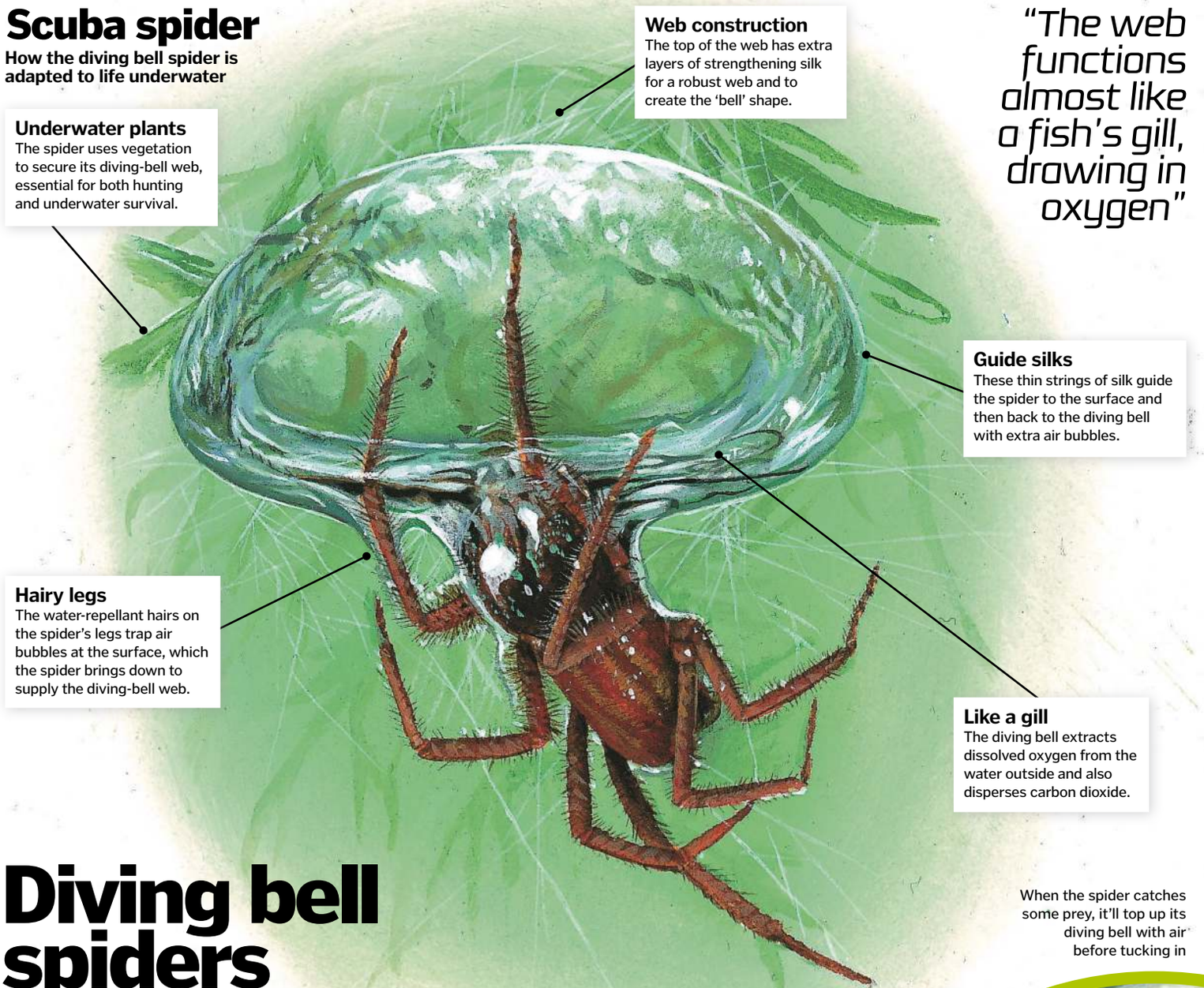
Picture a pig and your image probably includes a cute, curly tail. In the animal kingdom tails are used for balance, communication and many other purposes, but the purpose of curly pig tails isn't easy to root out. In fact, pigs often fight by biting each other's tails, so one theory is that they have evolved to be curly as this makes them harder to grab hold of. However, not all pigs have curly tails; wild boars and several other pig breeds have straightened tails, so it isn't clear why the evolution theory would apply to some breeds of pig and not to others.

Another explanation is that domestic pigs have been bred by farmers for hundreds of years. While breeding for characteristics that are helpful on the farm, such as docility, farmers may have also bred pigs with curly tails, if these traits are inherited together by coincidence. Among some breeds a curly tail is thought to indicate that a pig is happy and healthy, while a straightened tail is a sign of stress.

A curly tail may indicate a carefree pig

Scuba spider

How the diving bell spider is adapted to life underwater



Web construction
The top of the web has extra layers of strengthening silk for a robust web and to create the 'bell' shape.

Underwater plants
The spider uses vegetation to secure its diving-bell web, essential for both hunting and underwater survival.

Guide silks
These thin strings of silk guide the spider to the surface and then back to the diving bell with extra air bubbles.

Hairy legs
The water-repellant hairs on the spider's legs trap air bubbles at the surface, which the spider brings down to supply the diving-bell web.

Like a gill
The diving bell extracts dissolved oxygen from the water outside and also disperses carbon dioxide.

"The web functions almost like a fish's gill, drawing in oxygen"

Diving bell spiders

Check out the ingenious adaptations of these sub-surface arachnids

Just when you thought that the depths of ponds and lakes might be safe from these eight-legged critters, the diving bell spider is here to disturb the peace. A truly incredible adaptation allows this spider to spend the majority of its life underwater.

The water spider species (*Argyroneta aquatica*) lives in ponds and slow-moving waterways across Europe and northern Asia. It uses its web as a 'diving bell' — a principle that was supposedly tested first by none other than Alexander the Great in 332 BCE.

The water spider creates a web underwater, anchoring it to plants to secure it. It then makes several trips to the surface, trapping bubbles of air between the specialised hairs on its legs. The spider then heads back underwater to fill the web with these bubbles.

It was once thought that the spider continually had to supply the web with air, but recent research has shown that once filled, the spider can stay comfortably in the web all day (as long as it's not highly active). This is because the web functions almost like a fish's gill. As the spider consumes oxygen, the web draws in more dissolved oxygen from the water surrounding it, as well as dissipating the waste carbon dioxide. Were it not for nitrogen diffusion causing the web to shrink, the spider would be able to stay there indefinitely. Even so, the diving bell allows the spider to hunt, feed, mate and lay eggs while totally submerged.

When the spider catches some prey, it'll top up its diving bell with air before tucking in

Which systems will win the race to replace petrol in the drive to build a sustainable future?

HYDROGEN VS ELECTRIC

Hydrogen vs Electric HEAD-TO-HEAD

"Germany were the first to pledge to completely ban combustion engine cars by 2030"

Range
The Toyota Mirai has the longest range for a hydrogen car at 502km, while the Tesla Model S boasts an impressive 397-506km. However, on average, hydrogen cars have a better range, and the Tesla's maximum range would be rarely achievable in practice.

WINNER
HYDROGEN

Refuel Time
Hydrogen cell cars take just a few minutes to refuel, while even the very fastest superchargers take 30 minutes to fully charge an electric car.

WINNER
HYDROGEN

Speed
The fastest electric car on the market (the Nio EP9) can reach an impressive 312kph, but the Ford Fusion Hydrogen 999 triumphs with a top speed of 333kph!

WINNER
HYDROGEN

Infrastructure
Electric cars have the advantage of just plugging in almost anywhere. The infrastructure already exists, we just need to add charging stations at gas station or build them into homes. Hydrogen, on the other hand, is difficult to store and transport. It would have to be stored as gas and then transformed into liquid to enter the car: a complex, expensive and energy consuming process.

WINNER
ELECTRIC

Maintenance
Both electric and hydrogen cars are made from very few moving parts. This simplicity means that there is little that ever needs to be repaired or replaced, unlike a traditional internal combustion engine that is composed of hundreds of parts.

WINNER
DRAW

Cost
Hydrogen fuel is more expensive than fossil fuel options, and hydrogen cars are more expensive to buy. You can pick up an electric car for as little as £12,495 (approx. $16,500), while hydrogen cars are closer to £50,000 (approx. $66,000).

WINNER
ELECTRIC

Environmental impact
Electric and hydrogen can be produced in an environmentally friendly way, such as using solar power or hydropower, but currently our electricity grids are predominantly still using fossil fuels. Both hydrogen and electric vehicles are only as green as their source.

WINNER
DRAW

In the quest to protect and preserve our planet for generations to come, there is an increased urgency to design vehicles that will help to reduce air pollution and greenhouse gas emissions. We have more vehicles on our streets than ever before, and it is estimated that the gases from vehicles burning fossil fuels contribute approximately 13 per cent of the heat-trapping gases in our atmosphere.

Earth is already showing signs of climate change as temperatures have increased by 0.7 degrees Celsius over the last 140 years, causing Arctic ice to melt drastically, vast expanses of coral reef to suffer from mass die-offs and a significant rise in erratic weather. And it's not just our planet that is affected by this — our lungs are suffering too. The International Energy Agency estimates that every year 6.5 million people die prematurely because of poor air quality, making this pollution the biggest environmental risk to public health.

The future will be pretty bleak if we don't start changing the way we treat our planet, but there is hope. The last decade has seen a sharp rise in activism around the world to promote the importance of reducing fossil fuel emissions. We need to start powering our vehicles from sustainable sources, and many car manufacturers have jumped onboard to start doing this in conjunction with recent bans on fossil fuels being announced. Germany were the first to do this, pledging to completely ban combustion engine cars by 2030, and several other countries are following in their footsteps.

The sale of all new petrol and diesel cars will be banned in the UK by 2040, while Norway has pledged that by 2025 they will only be selling cars that are 100 per cent electric, with India set to do the same by 2030. Over half of India's population (more than 660 million people) are living in areas where the air quality has been determined unsafe, and it is estimated people

living there are having their lives shortened by up to three years. Piyush Goval, India's minister of railways and coal has commented, "The idea is that by 2030 not a single petrol or diesel car should be sold in the country."

ALTERNATIVES TO FOSSIL FUELS

The journey to find a suitable fuel to sustain our future has carried researchers and developers from solar engineering and compressed gases all the way to fuels made from seaweed or alcohol. One of the alternatives that is currently being investigated is powering motors using liquid nitrogen (LN_2). In this system, the specially designed engines heat the LN_2 gas before extracting the heat from the air and using the resulting pressurised gas to power the motor.

The UK supermarket Sainsbury's is trialling LN_2-fuelled Dearman engines in their lorries. They will replace the diesel engines used to power the refridgerators that keep food chilled when the vehicle's main engine is switched off. Though relatively cheap and certainly a green fuel solution, it is far from energy efficient, so it's unlikely that we could rely on this in the future.

Another attempt to find a green vehicle solution ditched the use of fuel altogether and built cars designed to be covered in solar panels to harness the power of our closest star. Though this sounds like a promising idea, and there are vehicles in use for solar car races, even the most efficient of this kind are limited by the amount of power they can collect because they are working with relatively little surface area.

So who are the lead runners in the race to find the power source of our future? Most experts agree that either hydrogen or electric cars will eventually prove to be the answer.

ELECTRIC CARS

Electric cars have been hailed as the future of motor travel, and they are becoming an increasingly common sight on our streets, almost silently navigating our roads. Pioneering automotive manufacturers like Tesla are leading the electric revolution, but many others have followed suit, and there are now a variety of electric cars available to the consumer.

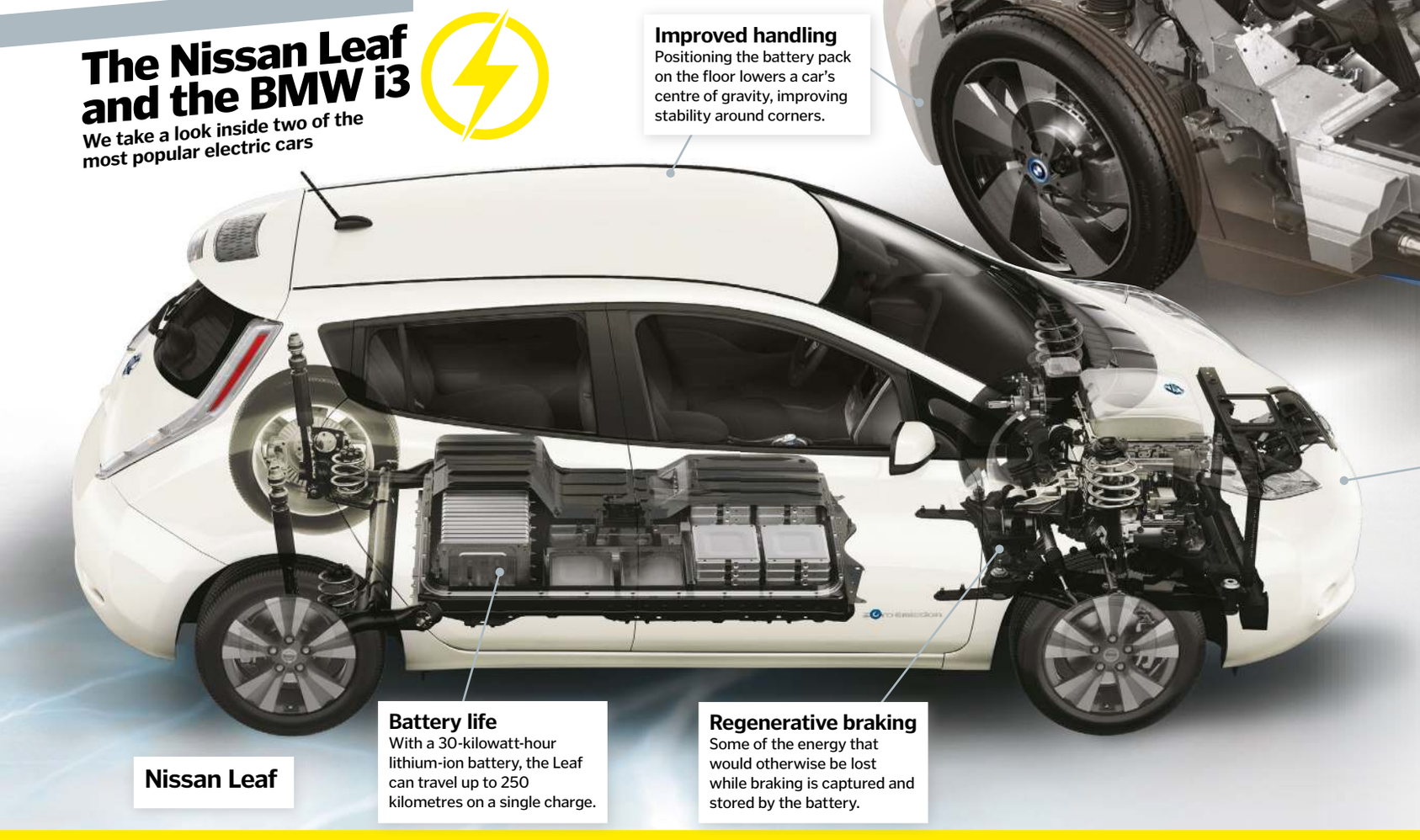
They can be charged at home or at charging stations, are fantastically cheap to run, and they don't emit any toxic gases. In some countries, such as the UK, the government are so keen to popularise electric vehicles that they will even contribute to the cost of your car.

With home charging ports the Leaf can easily be charged overnight

"Hydrogen and electric cars are only as green as their original electricity source"

The Nissan Leaf and the BMW i3

We take a look inside two of the most popular electric cars



Improved handling
Positioning the battery pack on the floor lowers a car's centre of gravity, improving stability around corners.

Battery life
With a 30-kilowatt-hour lithium-ion battery, the Leaf can travel up to 250 kilometres on a single charge.

Regenerative braking
Some of the energy that would otherwise be lost while braking is captured and stored by the battery.

Nissan Leaf

Recharging on the road

In efforts to overcome the two main concerns for people considering an electric car (range limitations and charging times) several car manufacturers have started to research dynamic wireless recharging.

This technology would enable vehicles to charge while they're moving over specially designed roads. The system consists of coils connected to electric cables embedded in the ground. The coils would generate an electromagnetic field, and as cars drive over them, a corresponding field would be induced in the car and converted into electricity.

This technology was demonstrated at a 100-metre test track earlier this year. Qualcomm Technologies and Vedecom installed the primary part of the dynamic charging system in a test track, while Vedecom and Renault installed the secondary part into two Renault Kangoos ZEs. The vehicles were able to charge up to 20 kilowatts while travelling over 100 kilometres per hour.

The Renault Kangoo ZE has recently been used to demonstrate dynamic wireless electric charging

BMW i3

Instant torque
Unlike conventional cars, there is no lag or gear switching with electric cars. Full power is available straight away.

Quiet ride
With no engines, electric cars are much quieter than petrol or diesel vehicles.

Better battery
The latest i3 model includes a 33-kilowatt-hour battery, providing a range of around 200 kilometres.

Optional engine
BMW offer an optional gasoline-powered range extender engine that will allow the i3 to travel for a further 100 kilometres before refuelling or recharging.

Tesla's Supercharger stations can charge their vehicles to over 80 per cent capacity in just 30 minutes

Though their popularity has been hindered by their charging times, limited recharge points and short driving range, there are solutions being engineered to overcome these issues, including on-the-go wireless charging that would mean never having to plug in to charge the battery.

HYDROGEN CARS

Hydrogen cars involve a more sophisticated level of engineering, as the electricity to power their motors is generated by electrochemical reactions. They work by splitting molecules of hydrogen into protons and electrons, with the latter flowing through a circuit. In general, hydrogen vehicles have a better range than electric cars, and they are much faster to refuel, taking just a few minutes rather than the hours it takes to charge an electric car with the current technology available.

With hydrogen, fuel is pumped into the car the same way you would top up with petrol or diesel. The real drawback of hydrogen cars is the lack of infrastructure. Hydrogen is difficult to store, so you're not able to drive freely and top up your tank anywhere. Though we are making strides in improving this, and there has been talk of having a system to produce hydrogen at home, for now this is a prohibitively expensive option. Additionally, there are concerns about the safety of hydrogen as it burns with an invisible flame, which could be dangerous if there was a leak.

POWERING THE FUTURE

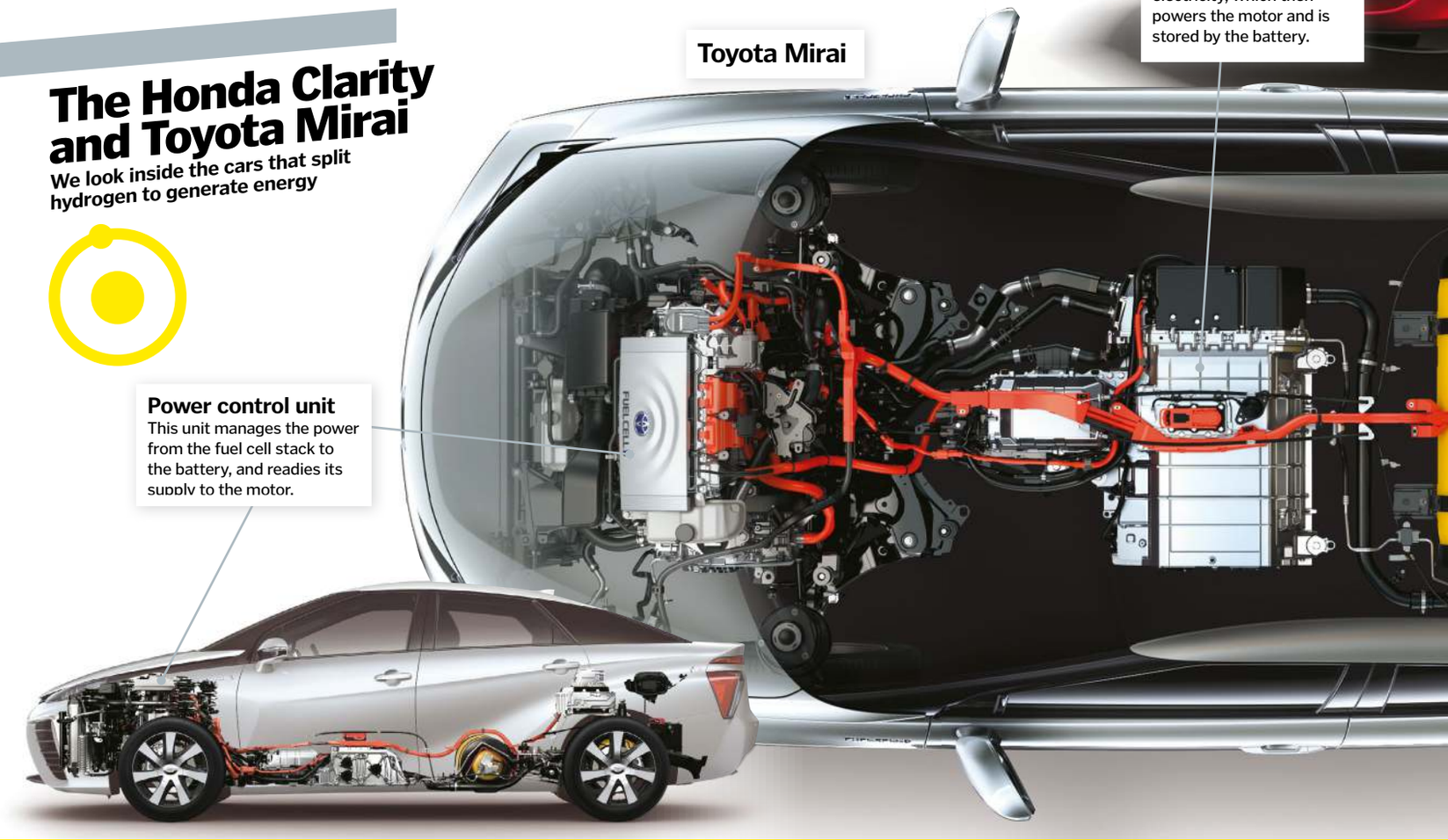
At the moment electric cars seem to be winning the race. Currently, there are only three hydrogen cars available on the market — the Toyota Mirai, the Hyundai ix35 FCEV and the Honda Clarity — which are relatively expensive and currently lack the infrastructure to really boom in the zero-emission vehicle market. There are now more than 50 electric cars to choose from and the infrastructure is largely there — we just need to plug in!

It is inspiring to think that soon our roads will be dominated by cars that will no longer contribute to air pollution on the streets. However, it is important to remember that both hydrogen and electric cars are only as green as their original electricity source. Though the popularisation of zero-emission cars is a huge step in the right direction, and we'll see a massive difference in air quality and greenhouse gas emissions as a result, the real revolution will be as we transform the national grid into a green power supply, running from solar, wind or water power rather than continuing to burn fossil fuels. The first challenges are to make zero-emission vehicles low cost and practical enough that they can become the norm, then build an eco-friendly infrastructure to support them.

The Honda Clarity boasts a five-person sedan layout, a first among hydrogen cars

The Honda Clarity and Toyota Mirai

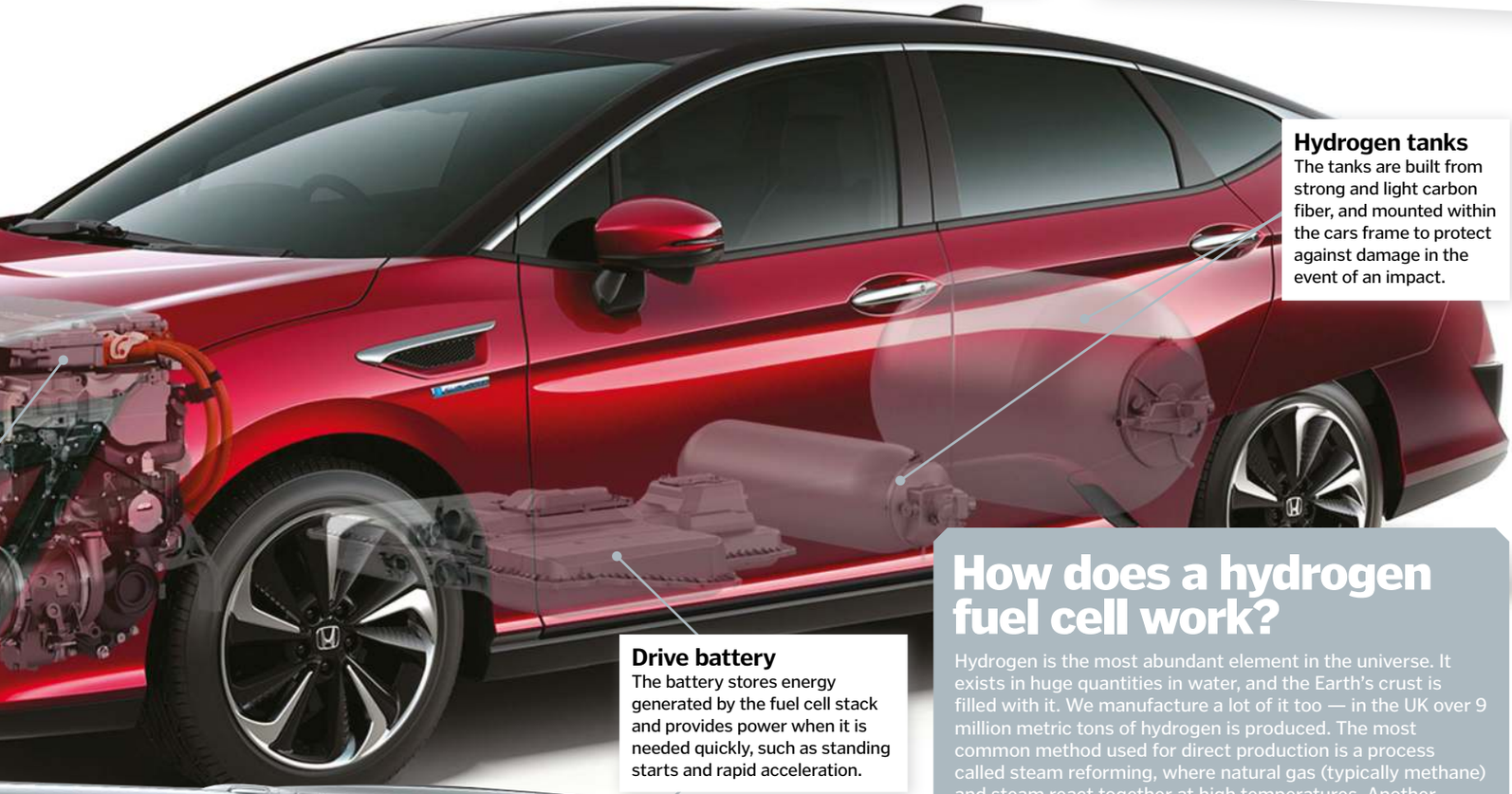
We look inside the cars that split hydrogen to generate energy




The Toyota Mirai is the world's first mass-produced hydrogen fuel cell vehicle

"Hydrogen fuel is pumped into the car the same way you would top up with petrol or diesel"

Honda Clarity



Hydrogen tanks
The tanks are built from strong and light carbon fiber, and mounted within the cars frame to protect against damage in the event of an impact.

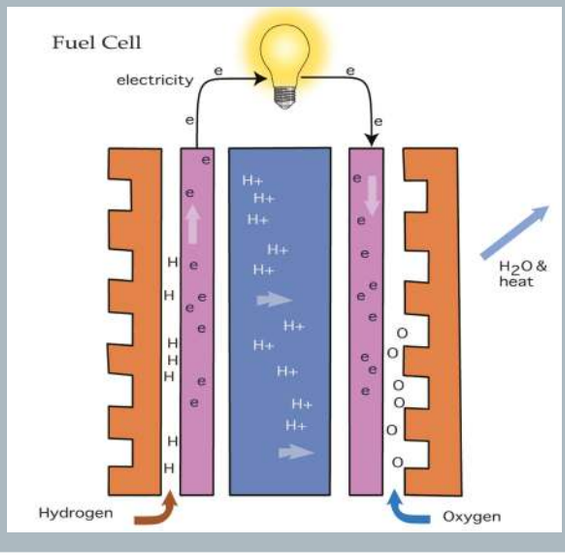
Drive battery
The battery stores energy generated by the fuel cell stack and provides power when it is needed quickly, such as standing starts and rapid acceleration.

Hydrogen tanks
The Mirai features two high-pressure carbon fibre tanks to maximise hydrogen storage.

How does a hydrogen fuel cell work?

Hydrogen is the most abundant element in the universe. It exists in huge quantities in water, and the Earth's crust is filled with it. We manufacture a lot of it too — in the UK over 9 million metric tons of hydrogen is produced. The most common method used for direct production is a process called steam reforming, where natural gas (typically methane) and steam react together at high temperatures. Another common method of hydrogen production is electrolysis, using a direct electric current in water to drive a reaction to split water molecules into hydrogen and oxygen.

A hydrogen fuel cell includes two sets of plates, two electrodes and two plates of platinum-based catalyst, separated by a plastic membrane. Hydrogen from a storage tank and oxygen from the air are fed through channels in the plate, and the catalyst splits the hydrogen molecules into protons and electrons. The protons can't pass through the membrane so are forced to pass through an external circuit, generating an electrical current.



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Cable ferries

Discover how cable ferries get from A to B without an internal engine

Manual ferries use a single cable laid between the two destinations and threaded through a cable windlass chain aboard the ferry. Turned by hand, the windlass collects the cable around its drum, pulling the ferry along the cable.

Powered ferries work in the same way as manually powered ferries, though typically on a larger scale. Rather than have a human turn a windlass, these ferries use a motor to power a chain sprocket to collect the laid chains. As a piece of innovative engineering, reaction ferries work in a similar way to a zip line, but instead of gravity moving you along the cable, it's the waters current. Attached by a traveller sprocket, reaction ferries use an oar and the currents of fast-flowing rivers to move along a high-suspended guide cable.

MANUAL — Stratford-upon-Avon

POWERED — Sandbanks, Poole

REACTION — Hampton Loade, Shropshire

Lightning strikes can leave scorch marks on planes, but the essential systems in modern aircraft will be left unscathed

Strikes on a plane

What happens when aircraft are hit by lightning? The answer might not be as terrifying as you think

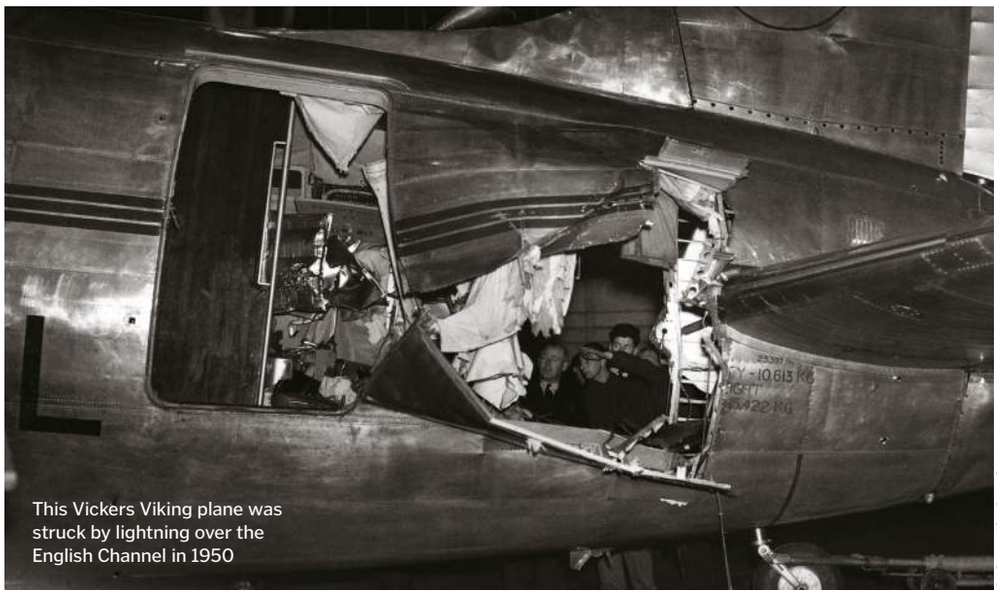
The thought of 1 billion joules of energy striking your airplane while you are trapped ten kilometres above the ground is the stuff of nightmares. But is it really as scary as it sounds?

It turns out that airplanes are pretty well-protected against lightning strikes and they no longer cause planes to crash. Though it is estimated that the average commercial plane gets struck once a year, the last plane crash caused by lightning was in 1967. This catastrophic accident killed all 81 crew and passengers on board after the lightning struck the fuel tank and caused a colossal explosion.

Since then engineers have made huge changes in plane designs and have enforced discharge and grounding precautions. Fuel has been refined so its vapours are less explosive, and fuel systems are well shielded to prevent sparks and resist burns. Modern planes are designed so that the electricity will be dissipated across the fuselage's surface if hit, in a process known as the skin effect.

This will happen naturally with planes built from aluminium, while crafts made from composite materials are constructed with a conductive mesh. This means there is usually no evidence that the plane was ever hit.

"It's estimated that the average plane is struck once a year"



This Vickers Viking plane was struck by lightning over the English Channel in 1950

© Alamy; Thinkstock

Self-driving lorries

Are autonomous trucks the future of the road haulage industry?

The future of trucking could create a much safer and more relaxed environment for everyone

It is estimated that the driver causes more than 90 per cent of accidents on the road, often due to tiredness, lapses in concentration, distraction or sometimes the influence of drink or drugs. So if most accidents are caused by human error, is it time to replace human drivers with machines? Some companies, including Google and Tesla, are starting to do just this with the creation of autonomous vehicles. In turn this has inevitably led to trucking corporations joining the game, which looks set to completely revolutionise the freighter industry.

The UK is set to spend £8 million ($10.6 million) trialling driverless lorries that use platooning technology, a system where several trucks drive in convoy, with the first controlled by a driver while the vehicles following are self-driving, capable of steering, braking and changing speed autonomously. As the platoon leader breaks, the trucks following in the convoy will do the same instantly and simultaneously.

A similar system is already in place in Singapore, where Scania and Toyota have been testing their self-driving buses and taxis on its streets. For the next three years the companies will operate a fleet of three driverless trucks following a manned platoon leader to transport cargo between ports.

However, taking the trucks from a controlled and predictable commercial environment on to heavily congested roads with other drivers is a new challenge altogether.

While it sounds like a massive development for the transport industry, it is actually only building on already established technology. It's expected that the lorries will operate in a similar way to driverless cars, with radar sensors positioned around the vehicle to monitor the

Daimler's Freightliner Inspiration Truck is the first autonomously driving truck with official road approval from the US state of Nevada

What are the benefits of driverless trucks?

By limiting human error, driverless trucks will likely make our roads safer. Unlike humans, machines don't require sleep to function properly, so accidents caused by fatigued truck drivers on the road will be reduced. An autonomous system also won't get distracted.

Another great advantage of autonomous lorries is they will have a positive impact on the environment by reducing emissions. HGV's running in close-running convoy will face reduced resistance as the air is pushed upward by the first truck and over the following vehicles. This will increase fuel efficiency, and therefore reduce CO_2 emissions. It's also expected that, without a driver, the trucks will be able to cover more territory, therefore reducing delivery time, as there will be no need to stop for breaks.

Additionally, this technology could help the industry in terms of staffing. Truck driving is a notoriously dangerous and difficult job, and currently it's proving difficult for the industry to recruit. However, this new technology would reduce the demand for human drivers.

Fuel efficiency will be improved as the lorries following the platoon leader will face less air resistance

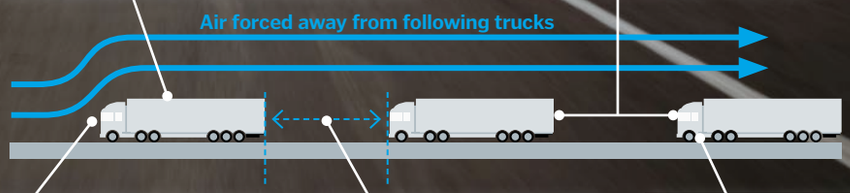
An extensive display will show the passenger the truck's status and speed

Platooning convoys

How will driverless lorries work on our roads?

Following the leader
This lorry will head the convoy and control all of the vehicles behind it. When the brakes are touched, the rest of the platoon will slow immediately.

Robot control
Computers will fully drive the trucks behind the platoon leader and will be responsible for everything from changing their speed to steering.



Drivers
A driver will sit in each of the following lorries to take over if needed. The trucks will warn the driver and give 20 seconds for the driver to take control, stopping automatically if this doesn't occur.

Sensory technology
A combination of radar, lidar, GPS and video cameras will be used by all of the trucks to detect the whereabouts of obstacles, other road users, pedestrians, cyclists and so on.

Access point
Access point in the cabs will keep the trucks wirelessly connected and able to communicate and react with each other.

location of nearby vehicles. They will also be equipped with video cameras responsible for detecting traffic lights, reading road signs and identifying obstacles, pedestrians and cyclists.

Detecting the edges of the road and lane markings is typically achieved using lidar sensors, which repetitively bounce light from the road. Ultrasonic sensors in the wheels can detect the location of curbs and other vehicles when parking, while a central computer analyses all of the data from various sensors in order to control steering, speed, acceleration and, most importantly, braking.

Some of these technologies are already on the road, such as autonomous emergency braking, which is already built into every truck in the UK — it can detect obstacles and automatically brake to avoid a crash.

Creating an autonomous truck is just joining all of these advancements together and refining them so it is safe and efficient for our roads.

Though safety concerns have been raised (such as how will a driverless car be programmed to respond to road rage, and what will happen if a car tries to squeeze between the small gap between two autonomous trucks in convoys) it is expected that the faster reaction times and more accurate spatial calculations will help to make our roads safer.

"If most road accidents are caused by human error, is it time to replace human drivers with machines?"

Record-breaking ROYALS

Meet the richest, deadliest and longest-lived monarchs and find out who had the most wives, the most money and the most heirs

"According to Forbes, King Bhumibols Adulyadej's wealth amounted to £22 billion"

Richest

King Bhumibol Adulyadej

1946–2016 / Thailand

In 2012, the Guinness World Record holder for the richest royal was King Bhumibol Adulyadej, King Rama IX of the Chakri dynasty of Thailand. According to Forbes, his wealth amounted to £22 billion ($30 billion), and his riches included the largest cut diamond in the world, a 545-carat jewel known as the Golden Jubilee Diamond.

King Bhumibol Adulyadej passed away in 2016, but no royal yet comes close to taking his title. The nearest is Hassanal Bolkiah, the Sultan of Brunei, who was reportedly worth £15 billion ($20 billion) in 2011.

Longest reign

Sobhuza II

1899–1982 / Swaziland

Queen Elizabeth II became the longest-reigning British monarch in 2015, outstripping the record set by her great great grandmother, Queen Victoria. But this doesn't yet match global records.

The longest reigning European monarch was Afonso I of Portugal, who racked up an impressive 73 years and 220 days between 30 April 1112 and 6 December 1185. However, the longest verifiable reign in history belongs to Sobhuza II, Paramount Chief and King of Swaziland, who assumed his position at just four months old and remained on the throne for 82 years.

Even longer reigns are rumoured but challenging to confirm. It's believed that ancient Egyptian pharaoh Phiops II ascended his throne at the age of six in 2281 BCE and remained there for 94 years, and Min Hti, King of Arakan (now part of Myanmar), reigned from 1279 to 1374, a total of 95 years.

Shortest reign

Sultan Khalid bin Barghash

25–27 August 1896 / Zanzibar

There are two Guinness World Record holders for the shortest reign of a monarch, each spending less than half an hour on their thrones. Louis-Antoine of France was heir apparent when Charles X abdicated after the July Revolution in 1830. He quickly abdicated too, passing the to Henry, Duke of Bordeaux, fleeing to Britain. Prince Luís Filipe of also lost his throne to a His father Dom Carlos I assassinated in the Regicide of 1908, and minutes later. these princes actually rule. The shortest reign monarch goes to Sultan Barghash, who lasted just after taking the throne in The British sent warships to his wooden palace, defeating him in the shortest war in history, the hour-long Anglo-Zanzibar War.

© Getty

Most travelled

Queen Elizabeth II

1952–present / United Kingdom and the Commonwealth

Modern monarchs have the upper hand when it comes to global travel, and Queen Elizabeth II has visited more countries than any other royal. In her time on the throne she has racked up more than 1.6 million kilometres, despite, amazingly, not having a passport.

As of 2012 The Queen had made state visits to 116 different countries, including all 53 Commonwealth nations, and by 2016, she'd made 256 official trips in total. But there are some places that remain off-limits. The Queen has not visited Israel, Egypt, Argentina or Greece, the homeland of Prince Philip.

ABOVE: Queen Elizabeth II during a 1975 visit to Hong Kong
RIGHT: The Queen and Prince Philip in Canada, July 1970

Face on most currencies

Queen Elizabeth II

1952–present / United Kingdom and the Commonwealth

Queen Elizabeth II appears on coins in more than 35 different countries, including Australia, Bahamas, Belize, Bermuda, Canada, Cayman Islands, Cyprus, Dominica, Falkland Islands, Fiji, Gibraltar, Guernsey, Hong Kong, Jamaica, New Zealand, Nigeria, Mauritius, Papua New Guinea, Rhodesia, Seychelles, South Africa, St Helena, and the UK.

Queen Elizabeth II's portrait has appeared on banknotes all over the world

Most heirs

King Abdulaziz Al-Saud

1932–1953 / Saudi Arabia

King Abdulaziz Al-Saud founded Saudi Arabia in 1932 and had 45 sons, from whom every Saudi king is descended. The number of daughters he fathered is not known, but Saudi Arabia's royal family now has over 15,000 members. His eldest son, King Saud, had 52 sons and 54 daughters.

Deadliest

Nurhaci, Tianming Emperor

1616–1626 / Liaoning, China

Nurhaci, the Tianming emperor, spearheaded the overthrow of the Ming dynasty. He was leader of the Manchu people of northern China, who were fed up with the famine, silver shortages and tax rises of the early 1600s. He put together a declaration of war known as the 'seven grievances', and the result was one of the bloodiest conflicts in recorded history. The Ming dynasty was replaced with the Qing dynasty and, in the process, an estimated 25 million people died. In the battle of Yangzhou, lead by Nurachi's son, Prince Dodo, 800,000 died.

Most wives

King Ibrahim Njoya

1886–1933 / Bamum (now western Cameroon)

Henry VIII is renowned for having six wives, but he doesn't come close to the record for royal spouses. King Ibn Saud of Saudi Arabia reportedly had 30; King Sobhuza II of Swaziland is rumoured to have had over 100; and King Ibrahim Njoya of Bamum had over 600.

Longest marriage

Takahito, Prince Mikasa Japan

This hotly contested record is currently held by Takahito, Prince Mikasa of Japan. He married Yuriko, Princess Mikasa, in 1941 and they were together for 75 years until his death in 2016. However, Queen Elizabeth II and Prince Philip are fast catching up: they married on 20 November 1947.

Takahito served in China during WWII, becoming a harsh critic of Japan's Imperial Army

"Queen Victoria's empire was the largest in history"

Widest rule

Queen Victoria

1837–1901 / United Kingdom of Great Britain and Ireland, India

The British Empire has its roots in the 16th century, but it wasn't until the reign of Queen Victoria that it reached its peak. Queen Victoria's empire was the largest in history, covering more than one-fifth of the world.

Competition with other European countries had driven the formation of British colonies, trading across the globe in tobacco, sugar, tea, silk, cotton, indigo dye and slaves. The first were set up in North America in the 1600s, then in Jamaica in 1655, and northwestern Canada in 1670. By 1661, the British began moving into Africa, settling an island in the Gambia River, and in 1788 the first settlements sprang up in Australia.

At the start of Victoria's reign colonies had appeared in South Africa, and during her time on the throne New Zealand and Egypt were added to the vast trading empire. In 1877 Victoria became Empress of India.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The Domesday Book

How this centuries-old tome reveals a crucial chapter in England's history

After William of Normandy conquered England in 1066 he possessed one of the wealthiest realms in medieval Europe — however, the new king did not yet know exactly how wealthy it was. After nearly 20 years establishing control of his kingdom, William commissioned a great survey to discover exactly what it was worth. Importantly, he wanted to learn how much tax could be raised from it.

The work was no small undertaking — a total of 13,418 settlements were surveyed across the country. Beginning in 1086, royal commissioners travelled from village to village recording who owned what and crucially its value. Every possession was counted, no matter how big or small, from the number of chickens kept to the size of workable fields. This wasn't just a Medieval 'Rich List' either, as all landowners and tenants were accounted for, from modest farmers to wealthy nobility.

All this information was painstakingly noted down in a huge tome called the Domesday Book, nicknamed after the Christian day of judgement. King William never saw the work completed as he died in 1087, but for historians it provides a valuable insight into 11th-century England.

The Domesday Book records the value of land before, during and after William's conquest

Cincinnati's lost subway

Why did this ambitious subterranean project hit a dead end?

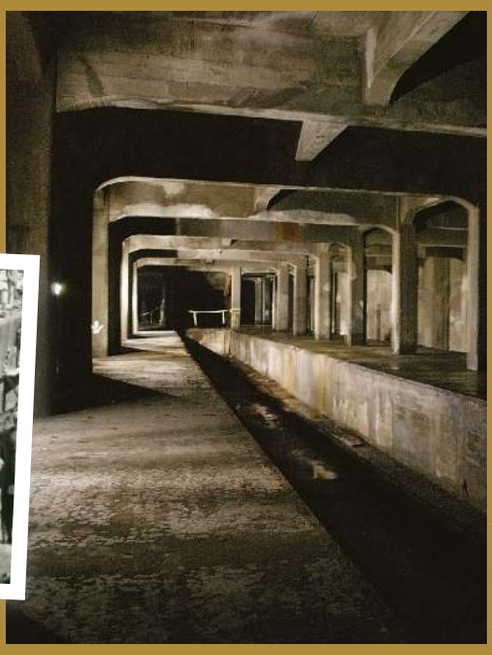
Beneath the streets of Cincinnati, Ohio, lies a network of platforms and over three kilometres of twin tunnels leading to nowhere. This empty concrete labyrinth is the result of a huge building project that has remained largely forgotten for nearly 100 years. In the early 20th century growing cities such as Cincinnati urgently needed to solve heavy traffic, so they constructed successful underground rail networks to deal with the problem.

As early as 1884 suggestions had been made to drain Cincinnati's canal and use it as the basis for a new subway, and by 1916 a 26-kilometre looping route was planned. However, the following year the US entered WWI and the $6 million (£4.4 million) bond required for the construction was withheld. The 'Rapid Transit Loop', as the project was to be known, was put on hold.

Once the war was over finances were released, and in 1920 construction finally began. However, over the years the subway had become a heated political issue, and it was discovered that much of the original $6 million budget had been squandered. By 1927 a lack of funds, political in-fighting and the growing popularity of automobiles derailed the project completely, and it remains incomplete to this day.

The twin tunnels of the Cincinnati subway, under construction in the 1920s

Race Street Station was one of the 20 planned platforms in the subway and one of only three that remain



The catacombs of Kom El-Shoqafa

Discover one of the seven wonders of the Middle Ages

On the northern coast of Egypt, in the bustling city of Alexandria, lay the catacombs of Kom El-Shoqafa. The tomb's Arab name was given in recognition of the Greek name Lofus Kira, meaning 'Mound of Shards'. Discovered in 1900, it wasn't a team of archaeologists that stumbled across these cavernous tombs, but a wayward donkey. If stories are to be believed, an unfortunate stray donkey was swallowed by the parting earth of a hilltop at the site of an ancient village known then as Rhakotis.

Initially intended to house the remains of one affluent family, a total of 300 bodies have been found within. Originally built during the Greek-Roman era during the turn of the second century CE, Egyptians used the underground monument up until the fifth century CE.

Constructed from the surrounding oolitic limestone (stone naturally formed from sand and shell particles), stone pillars and walls would have been erected by hand using simple tools. Descending from the surface entrance, a ten-metre cylindrical staircase leads to a triclinium, a Roman banqueting hall for grieving families, and the rotunda. Bodies of the deceased were lowered down the staircase shaft and carried through to the main tomb to their final resting place.

Kom El-Shoqafa would not have been the only tomb in ancient Alexandria. Subterranean tombs were a part of a Necropolis 'city of the dead' in ancient Egypt. It is presumed that other tombs may have been destroyed as a result of earthquakes and urban development.

Bereaved family members would gather in these meditation rooms for quiet contemplation

The funeral chapel was the entrance down into the circular staircase to the main tomb

The catacombs descend into three levels; the third is now completely submerged in ground water

"A total of 300 bodies have been found within"

A mix of inspiration

The catacombs of Kom El-Shoqafa host some of the most unique decorations and sculptures seen in ancient tombs, combining influences from three different cultures.

Egypt
Anubis, the ancient Egyptian god of the dead.

Roman
Traditional Egyptian figures are dressed as Roman legionaries throughout the tomb.

Greek
Agathos Daimon, referred to as the 'good spirit'. The tomb is filled with carvings of the serpent for protection.

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The deadly art of duelling

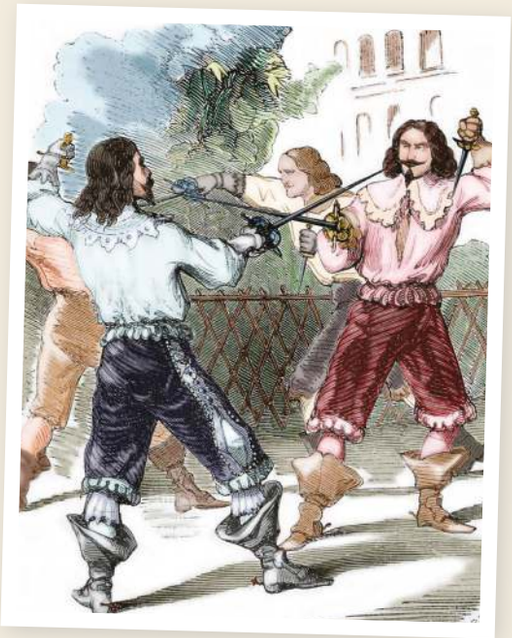
When honour was at stake, a gentleman's only option was to cross swords

For centuries, settling a dispute through armed combat was not only customary, it was a highly respected ritual reserved for the upper class. These fights, known as duels, would occur when a man's honour was questioned or brazenly offended. For a proud gentleman personal or family honour was worth more than gold, and although duels usually ended when the first blood was drawn, some were fought to the death.

Duels were carefully organised and followed a code of conduct, which separated them from medieval trials of combat and ancient forms of contest. They became a cultural norm throughout Europe during the Renaissance era, when the nobility commonly carried razor-sharp rapiers as a symbol of their wealth and status, as well as for protection.

Blades remained the primary weapon of choice for duels until the development of pistols saw combatants aim gunshots at one another instead of sword blows. In these arguably deadlier duels, men would often try not to kill their opponent, shooting wide of the target. However, one of the most notorious duels in US history saw politician Alexander Hamilton shot dead by Vice President Aaron Burr in 1804.

Duelling eventually became outlawed in many countries, but the practice continued in secret up until the early 20th century. As one historian put it, the First World War was "a duel that virtually ended duelling".



To make it a fair fight, swords had to be of a similar length

En garde! A gentleman's guide to restoring his honour through swordplay

1 Issue a formal challenge

If a fellow gentleman makes a rude remark about your wife (or worse) challenge him to a duel. Write down your grievances in a letter and demand satisfaction. In the unlikely event the rapscallion refuses, call him a coward.

2 Arrange a time and place

Choose a friend to be your 'second'. He will meet with your enemy's second and the pair will do their best to reach a compromise. If bloodshed is unavoidable, they will arrange a time and place for the duel and prepare the weapons.

3 Abide by etiquette

When gentlemen fight they follow the Code Duello, or 'code of duelling', which sets out the rules for dignified duelling behaviour. These can vary, but usually the challenged party has the right to choose the weapon.

4 Prepare to fight

The challenged party gets to choose the location, but your second will scour the ground in search of unfair advantages. The duellists must also prove they're not wearing any protection. It's a sensible idea to have a doctor present.

5 Keep calm in combat

Get into position by standing the agreed number of paces apart and only begin duelling once the signal has been given. To uphold your reputation you must show courage at all times during the duel.

6 Honour is restored

The duel is over when blood is drawn and honour is restored. Of course, it's not always the offended party that declares victory, and sometimes it's the opponent who gets to add injury to insult.

The metal rivets reinforce the stitching to make the garment last longer

Main image: Lumberjacks in Oregon, US, wearing Levi's jeans in 1880
Inset: An advert from 1874 targets the working class

The birth of blue jeans

The 'riveting' story of how two visionary immigrants created an American classic

Denim jeans are a fashion essential around the world, but their origins are much more humble. During the late 1800s, America was in the full throes of the Gold Rush, and Jacob Davis, a Latvian immigrant, was working as a tailor in Nevada. Jacob sold clothing to local miners and workmen, who required strong and hard-wearing material for their work. It was here that Jacob struck gold.

By fixing small copper rivets to the most strained areas of the garment, such as the pockets, he created a much more durable design. This new, robust clothing caught public attention and Jacob's 'waist overalls', as they were known, became so popular that he sought a patent to protect his idea. But a patent required money, so he asked his fabric supplier, Levi Strauss, for help.

Bavarian-born Strauss had also travelled to the States to seek his fortune and saw potential in Jacob's product. The pair were granted a patent in 1873 and before long the modern denim jean was being worn in factories, farms and mines across the country. Indigo was chosen to dye the jeans because it was dark enough to hide stains, it didn't penetrate the woven fabric and, crucially, it was cheap.

When the patent expired in 1908 dozens of imitations flooded the market and in the decades to come were worn by men and women of all classes. Teenagers began calling them 'jeans' instead of 'overalls' and manufacturers officially adopted the term in the 1960s. Today their popularity is as durable as the original riveted design.

Denim by the decades

How have jean styles changed over the years?

5 jean-ius facts

Denim jeans is a misnomer

In the late 1700s, two cotton fabrics were produced: denim and jean. Denim, originally made in de Nîmes, France, was more durable and thicker than jean, used to make workers' trousers in Genoa, Italy.

They were almost banned

Jeans gained a 'bad boy' image after featuring in movies like *Rebel Without A Cause*. Schools began banning them, so Levi's ran a campaign starring a clean-cut, denim-clad kid with the slogan 'Right for school'.

Levi wasn't his real name

He was born Loeb Strauss, but like his future business partner, Jacob Davis, he changed his name after immigrating to the US. Eventually Levi set up a wholesale dry goods business in San Francisco.

Duck or denim?

When Levi and Jacob began mass-producing their waist overalls, they manufactured two kinds. One was from blue denim and the other from brown cotton duck — a tough canvas material that was used to cover wagons.

Built to last

In the Levi Strauss & Co archives lies two pairs of jeans dating from the late 1870s or early 1880s, which are thought to be the oldest in existence. Only two people know the combination to the fireproof safe that protects them.

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MEET THE EXPERTS

Who's answering your questions this month?

Laura Mears

Laura studied biomedical science at King's College London and has a master's from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Franklin-Cheung

Having earned degrees from the University of Nottingham and Imperial College London, Alex has worked at many prestigious institutions, including CERN, London's Science Museum and the Institute of Physics.

Tom Lean

Tom is a historian of science at the British Library where he works on oral history projects. He recently published his first book, *Electronic Dreams: How 1980s Britain Learned To Love The Home Computer.*

Katy Sheen

Katy studied genetics at university and is a former **How It Works** team member. She now works for a biomedical journal, where she enjoys learning about the brilliant and bizarre science of the human body.

Joanna Stass

Having been a writer and editor for a number of years, **How It Works** alumnus Jo has picked up plenty of fascinating facts. She is particularly interested in natural world wonders, innovations in technology and adorable animals.

Water-soluble hormones like insulin act by attaching to receptors on the target cell membrane

What are hormones?

Gina Clare

Hormones are long-range chemical messages used to send signals via the blood. They are produced by glands and they control all aspects of your biology, from growth and repair to metabolism and reproduction. Fat-soluble hormones like oestrogen and testosterone are made from fats like cholesterol. They go straight through the membrane of cells and into the nucleus, where they switch genes on and off. Water-soluble hormones like insulin and adrenaline are often made from short fragments of protein known as peptides. They can't travel through cell membranes, so cells detect them using specialist receptors, which trigger cascades of signals to change cell behaviour. **LM**

Can eating before exercise cause a stitch?

Tyrone Kelly

Yes, but scientists aren't completely sure why. Stitches are thought to be caused by cramp in the diaphragm, which is connected to the spleen, liver and stomach by ligaments. When you exercise these organs move around and, if your stomach is full, this might cause pain. Another suggestion is that a full stomach could rub against the parietal peritoneum, a slippery covering that coats the organs in the abdomen, causing friction and discomfort. **LM**

What were the Crusades?

Liam Chase

The Crusades were a series of religious conflicts that began when the Muslim Turks banned European Christian pilgrims from the city of Jerusalem. The First Crusade was called by Pope Urban II in 1095 when he promised pilgrims forgiveness of their sins if they could recover the Holy Land. Over the next few centuries there were eight more Crusades, but each time the Crusaders either failed to win or failed to keep any of the territory they had conquered. They did, however, gain a great deal of knowledge from the more scientifically advanced Muslims, including better castle designs and a new number system. **JS**

Cosmonaut Alexei Leonov makes the first spacewalk in 1965, but it almost went badly wrong

Who performed the first spacewalk?

George Dean

Soviet cosmonaut Alexei Leonov conducted the first spacewalk, lasting 12 minutes, on the 1965 Voskhod 2 mission. It was almost a disaster: in the vacuum of space Leonov's space suit inflated like a balloon, making it impossible for him to fit through the airlock back into his space capsule. With only minutes to spare, Leonov let some air out from his suit, risking decompression sickness but deflating it enough to squeeze into the airlock alive. **TL**

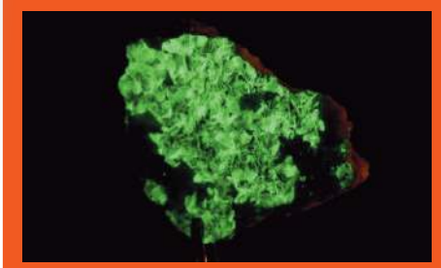
How do beavers build their dams?

Jenny McKinnon

Beavers build dams on rivers to create sheltered ponds. The dams act as a protective moat for the lodges where beavers live and allow them to swim to food sources safely. Families of beavers cut down trees with their powerful teeth and drag wooden poles to stick vertically into the mud at the river bottom, then crisscross these with branches to make the dam's structure. Sometimes they will add stones too. Finally, the beavers seal the dam using mud dredged up from the riverbed so it can hold water in effectively. **TL**

Which is the rarest naturally occurring element?

The rarest element to occur naturally on Earth is astatine. Found deep in the Earth's crust, there are less than 30 grams of it in existence at any one moment. **AC**



Why do birds fly into windows?

When they see the sky and surrounding environment reflected in a window, birds sometimes don't realise that there is a glass pane ahead, leading to a collision. **AC**

What's the biggest selling song of all time?

According to the Guinness World Records, it is Bing Crosby's 1942 hit *White Christmas*, which was written by Irving Berlin and has sold an estimated 50 million copies worldwide since its release. **JS**

What is the furthest object you can see in the night sky with the naked eye?

In dark skies away from light-polluted areas, those with good eyesight should be able to see the Andromeda Galaxy, the nearest large galaxy to us at 2.5 million lightyears away. **JS**

BRAIN DUMP

Rapid action can limit the devastating environmental impacts caused by oil spills

How are oil spills cleaned up?

Yan Hu

Three main techniques are commonly used to limit the spread of oil after a spill: skimming, dispersants and in situ burning. First of all booms (floating barriers) are deployed to physically contain the oil, which floats on the water surface. Skimmers are absorbent materials or boats that collect oil. Chemical dispersants act like washing up liquid, splitting the oil up into tiny drops that bacteria can break down further. Finally, in situ burning involves setting fire to the oil. The most appropriate method depends on the environment, weather conditions and type of oil. **AC**

Eggs, fish, nuts and meat are all good sources of protein

Does eating protein help you feel full?

Bobby Harrelson

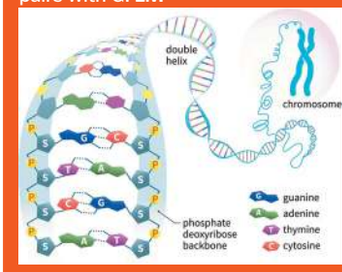
Scientific studies have found that eating a protein-rich meal does indeed generate the feeling of satiety. Peptides, which are produced when you digest dietary proteins, block mu opioid receptors (MORs) on nerves found in the major blood vessel that drains blood from the gut. These receptors modulate food intake and so blocking them curbs your appetite. In addition, peptides also send signals to the brain that then stimulates the intestine to release glucose, suppressing your desire to eat. **JS**

Can stress really cause hives?

Yes, according to the NHS, both emotional and physical stress can. The red rash is linked to the release of a chemical called histamine, which causes itchy swelling. **LM**

What are DNA bases?

The bases in DNA are adenine (A), cytosine (C), guanine (G) and thymine (T). They are the chemical 'letters' that store the genetic code. The double helix structure of DNA is maintained by pairs of bases linking together like the rungs of a ladder. A always pairs with T, and C always pairs with G. **LM**



How many data centres does Google have?

Google has 15 data centres, which are enormous computing facilities filled with the equipment that allows Google to operate. Most are in the US, with a few in Europe, Asia and South America. **TL**

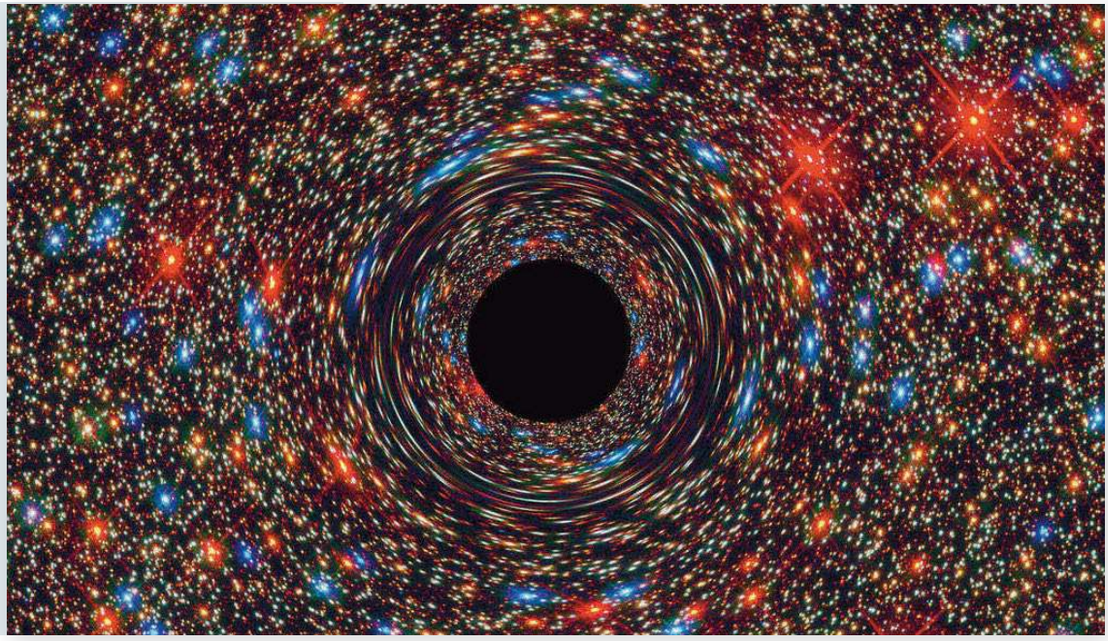
Which Roman emperor served the longest?

Augustus (pictured), the first emperor of Rome, reigned for 41 years, longer than any other. However, the Roman Empire was later split in two, and one emperor of the East, Theodosius II, reigned for 42 years. **TL**

How do we know that black holes actually exist?

Nelson Estevez

Since no light can escape from a black hole, it's impossible to see them, but several clues give away their existence. A black hole's powerful gravitational field pulls on nearby stars, affecting their motion and allowing astronomers to infer that they must be orbiting a black hole. As gases spiral closer to a black hole they heat up to millions of degrees, emitting X-ray radiation that can then be detected by space telescopes. **AC**



Is platinum rarer than gold?

Stevie Vernon

Platinum is rarer than gold and mined in much smaller quantities. In 2013, only 179 tons were mined. If formed into a single block, it would only be the size of a car yet it would be worth $8 billion. In the same year, 2,982 tons of gold were mined, worth $125 billion. **KS**

Ballet dancers are trained to shift their weight away from their toes while en pointe

Do ballet dancers damage their feet by dancing en pointe?

Cassie Yelverton

Ballet dancers perform with perfectly pointed toes using shoes that have solid blocks built into them. While this may look elegant, balancing on the tips of the toes puts enormous strain on all the joints of the foot. Professional ballet dancers often suffer from broken nails, bruised joints and swollen ankles as a result of a busy schedule of rehearsals and shows. In the long term, dancing en pointe can even cause the cartilage in the toes and feet to degenerate. **KS**

What colour are our eyes most sensitive to?

William Earl

Under normal lighting conditions, the human eye is most sensitive to a yellowish-green colour. However, when it's darker, our eyes are more sensitive to blues and purples. **KS**

Over 100 species of orchid rely on wasps for pollination

What would be the impact of wasps going extinct?

Penny Newton

The importance of bees to the environment is a hot topic right now, but their buzzy cousins are critical too. Wasps prey on spiders, insects and mites, keeping their numbers controlled. Some of these prey species are pests, meaning wasps reduce the amount of pesticides farmers need to use. Many species of wasp are also pollinators, vital to many plant species. Even wasp stings may be useful: scientists are investigating the use of their venom in cancer treatments. **KS**

Ad Astra

Learn how to travel to the stars with this illustrated guide

- Author: **Dallas Campbell**
- Publisher: **Simon & Schuster**
- Price: **£16.99 (approx. $23)**
- Release date: **Out now**

Space travel understandably captures the imagination of people around the world. When Tim Peake visited the International Space Station in 2015, the story of his journey was not only told in classrooms and in newspapers in the UK — it was covered around the globe. The mystery of the cosmos is incredibly interesting, which is perhaps why *Ad Astra* is such an engaging read.

The book aims to cover every part of space travel, but rather than simply explaining the history of the scientific exploration of space chronologically, author Dallas Campbell instead suggests that we take a trip with him up into the stars to see them for ourselves.

As such, the book begins by explaining how to build rockets, whether or not you can take your dog with you, and explores the tests that astronauts need to pass if they want to make it to the launchpad. From there it discusses the realities of space travel, from the suits you wear to the food you eat, before venturing further to predict the future of space travel and discuss the idea of visiting Mars and beyond.

Campbell's writing style is light and conversational, with regular asides and footnotes that will raise a smile. However, don't be fooled — a huge amount of research has gone into writing *Ad Astra*, and as a result you'll find all kinds of unmissable stories and facts within his prose. We were astonished that one test for prospective astronauts included folding 1,000 origami cranes — to prove you had what it takes, every one had to be identical!

Later in the book we were gripped by the story of Michael Foale, an astronaut on the ISS who had helped three Russian cosmonauts when the station was struck by a supply craft that failed to dock correctly. It was only the hard work, quick thinking and mathematical smarts of the astronauts that stopped the station from becoming another piece of wreckage spinning around the Earth. Interviews with astronauts are spread throughout the book to offer some hands-on insight too.

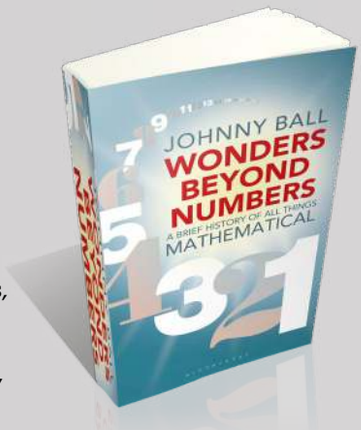
There are times when we wanted a little less detail on some aspects of space flight and a little more on others. But these were few and far between — for the most part *Ad Astra* proved to be an excellent way of exploring space without leaving the comfort of your armchair. Therefore it's a highly recommended read for anyone with a love of outer space.

★★★★★

Wonders Beyond Numbers

Mathematical marvels explained

- Author: **Johnny Ball**
- Publisher: **Bloomsbury**
- Price: **£16.99 / $27**
- Release date: **Out now**



The best way to make a subject accessible is to have it introduced by someone who is utterly in love with it. In the case of mathematics, who better than Johnny Ball?

The star of TV shows like *Think Of A Number*, *Knowhow* and *Johnny Ball Reveals All*, his approach is one geared towards making the subject understandable to all while grounding its importance in a historical context. To this end, Ball's lessons draw heavily on figures like Hipparchus and Pythagoras, hammering home just how important their work has been to the subject as a whole.

His lessons aren't always rooted in the distant past, though. Lesser-mentioned figures like Nikolai Ivanovich Lobachevsky and Friedrich Kekulé are also remarked upon, as is the subject's importance to fields like astronomy, computing and more, all the while pervaded by a sense of passion that remains infectious.

Mathematics-phobes might remain stubborn to transition, but for everyone else this is a potentially great primer in loving a subject that hasn't always been easy to love.

★★★★☆

Eureka: How Invention Happens

Back to the start

- Author: **Gavin Weighman**
- Publisher: **Yale University Press**
- Price: **£10.99 / $18**
- Release date: **Out now**

No matter how revolutionary the invention, chances are there was a progenitor to it; MP3 players existed before the iPod, after all.

Rather than providing a list of breakthroughs, author Gavin Weightman instead chooses to focus on five particularly notable inventions: the aeroplane, the television, the mobile phone, the computer, and the bar code, working backwards from the 'eureka moment' that changed things all the way back to its earliest origins as a germinating seed of thought.

This superficially narrow approach proves to be a sensible idea, giving us the opportunity to delve deeper into the history of these influential items, delivering a series of surprising revelations along the way. For instance, did you know that one of the aeroplane's earliest inspirations comes in the form of the humble bicycle? Or that the barcode's inspiration is derived from a theory put forward by none other than Albert Einstein?

The best part is that the above paragraph provides just two of the numerous pieces of trivia interspersed among its pages. This book is guaranteed to make you look at the world differently.

★★★★★

Extreme Machines

Crash bang wallop

- Author: **Anne Rooney**
- Publisher: **Carlton**
- Price: **£14.99 / $19.95**
- Release date: **Out now**

Seemingly designed with the intent of catching the eyes of excitable young kids in the hope that they will subsequently persuade their parents to buy this for them, *Extreme Machines* lives up to its titular mantra well.

From high-speed trains and submarines to jet packs and spyplanes, the creators of this book have done a great job of making this book genuinely difficult to return to its place on the bookshelf. While the text is minimal — massive pictures of the aforementioned behemoths are the focus here — this fits in entirely with its young target audience. Even better, its educational value is sky-high, making it the perfect book to trick your kids into reading. Expect to have all manner of monster truck-themed trivia thrown at you upon purchasing this.

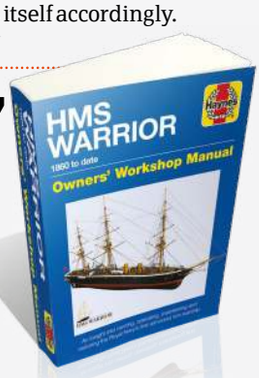
As we mentioned, its appeal is probably limited to young children (we reckon ten and under), but that's no bad thing. *Extreme Machines* knows its target audience and conducts itself accordingly.

★★★★☆

HMS Warrior: Owners' Workshop Manual

Man the guns

- Author: **Richard May**
- Publisher: **Haynes**
- Price: **£25 / $36.95**
- Release date: **Out now**



Throughout its active service during the second half of the 19th century and into the 20th, there were few battleships more feared or awe-inspiring than the mighty HMS Warrior.

The last surviving member of Britain's once 45-strong 'Black Battlefleet' that dominated the seas, Haynes' latest manual marks 30 years since its arrival in Portsmouth harbour by providing a customarily insightful and in-depth examination of it, delving into its construction, lifetime and influence as its place in history is assessed, as well as looking at the restoration process that allowed it to live on.

As with most Haynes books, your interest in this will be directly proportionate to how much investment you have in the subject matter. While it's all very accessible and lovingly presented, it might be hard to persuade those who don't count themselves among the number of maritime enthusiasts to give this a go.

Even so, they could do worse than give this try. Providing not just a worthy ode to a much-respected participant in Britain's naval history but also a side-glance of the nation's growth in these years, Haynes has done it again.

★★★★☆

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

Wordsearch

B	G	A	Z	E	M	L	E	U	D	P	I	E	V	N
A	L	L	I	R	H	T	B	M	O	C	A	T	A	C
L	L	A	H	W	X	C	W	T	E	N	I	L	Z	K
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C	I	N	C	I	N	A	T	T	I	X	P	G	K	U

FIND THE FOLLOWING WORDS...

BLACKHOLES
WILDFLOWERS
CATACOMB
MONARCH
LASER
SEASHELL
GLAZING
CAMOUFLAGE
PIGS
HYDROGEN
ELECTRIC
CINCINATTI
DUEL
RADIATION
CHEMISTRY
MIRAGE

Spot the difference

See if you can find all six changes we've made to the image on the right

Quick-fire questions

Q1 How many US presidents feature on Mount Rushmore?

- Seven
- Three
- Four
- One

Q2 How long do NASA astronauts typically stay on the ISS?

- 6 hours
- 6 days
- 6 weeks
- 6 months

Q3 Which Australian city lies the furthest west?

- Sydney
- Adelaide
- Darwin
- Perth

Q4 What is the name of the clocktower at the Palace of Westminster?

- Victoria clock
- Westminster spire
- Big Ben
- Elizabeth Tower

Q5 The distance between the Earth and Sun is _____

- 12 parsecs
- 1 AU
- 3,000km
- 1 lightyear

Number squares

Complete the grid by multiplying the values in the rows and columns. Time yourself and see if you can beat the team!

x	9	3	7	10	8	2	4	6	5	1
4										
5										
6										
10										
8										
1										
7										
3										
9										
2										

What is it?

A .....

BEAT THE TEAM...

- **Jackie** 03m 24s
- **Charlie** 04m 03s
- **Laurie** 03m 17s
- **Charlie** 04m 15s
- **Duncan** 04m 35s
- **Scott** 03m 25s

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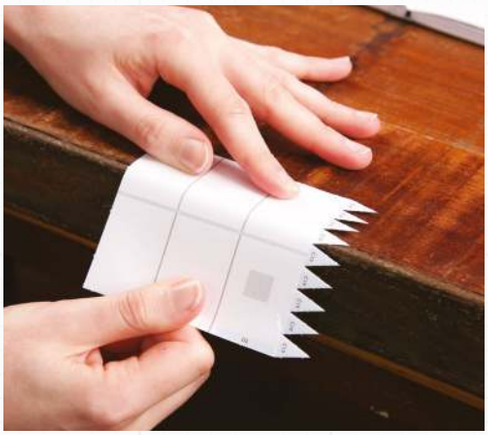
Build a rocket with Space Racers

Create some of the world's most famous rockets using just paper and glue

BUILD YOUR OWN

THIS GREAT KIT BY AUTHOR ISABEL THOMAS IS OUT NOW FROM LAURENCE KING PUBLISHING



1 Get prepared

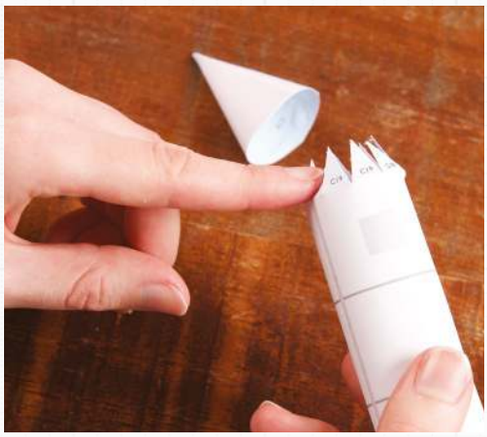
The first thing you'll need to do is gather your equipment. The things you'll need the most are PVA glue and a brush, as all of the rockets will require you to stick different parts together. Other useful tools include a pencil (useful for rolling the paper to curve it) and a lolly stick, which will help you reach into the rocket when you need to stick things inside.

2 Roll out

There are a few handy ways to roll out different shapes. You'll be making a lot of tubes as you build you rockets, as cylinders topped with cones are very aerodynamic. When you are creating a larger tube, one easy way to make sure your card curves evenly is to put it on the edge of a table and hold it with one hand, then drag the other edge downwards.

3 Smaller cones

As mentioned, you will also be making a lot of cones, as these will form the front of most of the rockets you build. When you are making them, getting the point of the cone sharp is quite difficult. Use the point of the pencil right at the point of the cone, and when you fold it around you can make sure it stays pointy, so your rocket will take off perfectly!



4 Fold them in

When you are attaching a cone to another section, there will be several small triangular flaps that allow you to attach the two together. Make sure you fold these in first before you put the two sections together, and put glue on each one individually. Then put the sections together, and either use that lolly stick or your finger to press the flaps onto the other section to secure them.

5 Let it dry!

The most important tip we can give you is to let your glue dry for as long as possible before you work on a section again. So, if you're attaching a flap to a section, attach the first part, then leave it for a few minutes (or more) to dry before you attach the second part. You can work on other parts while you wait, though. Doing this will make your finished rocket stronger.

6 Follow the instructions

The instruction booklet uses a simple number and letter system to show you what you need to do. Our top tip is that if you ever get confused, look at the letters on the pieces themselves. The letter surfaces will always stick together so that you can no longer see the letters. Stick to the instructions, though, and you shouldn't find anything too complicated.

"It is important to let your glue dry for as long as possible"

NEXT ISSUE

MAKE SYCAMORE HELICOPTERS

BUILD A SOLAR TOWER

In summary...

The simple pop-out shapes make this project all about the creation of the rocket. You don't need to worry about cutting anything out — just push them out of the book and stick them together! Some parts can be tricky to get right, but it's well worth persevering as the finished products look great.

Disclaimer: Neither Future Publishing nor its employees can accept liability for any adverse effects experienced after carrying out these projects. Always take care when handling potentially hazardous equipment or when working with electronics and follow the manufacturer's instructions.

7 Stick along the lines

When you're sticking multiple sections of the rocket together you might think that lining up the folds in your cylinders will make the whole rocket shape a little weaker, but as long as you've left the glue to dry fully this won't be a problem. Keep all your joins in line to get the patterns on the rocket right and to ensure any other sections that might need to be attached will line up properly.

8 Lift off!

Once you've followed the instructions fully, you should have a rocket standing tall in front of you. If you find your gluing has not been as neat as you'd hoped and your sections aren't completely straight — don't worry! You can always use some sticky fixers or clear tape to secure any stubborn pieces. There are ten models of rocket in total: seven are famous designs from history, while one is a futuristic concept called the Skylon. There are also two blank rockets that you can decorate yourself to create a custom model.

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WIN!
AMAZING PRIZE FOR LETTER OF THE MONTH!
100 STEPS FOR SCIENCE
This visual guide by Lisa Jane Gillespie and Yukai Du explores humankind's most important discoveries and is a wonderful blend of science and art

Letter of the Month

Mortality & spiderwebs

Dear **HIW**,
I really love reading your magazine! There is so much interesting stuff to read about on every page! I particularly enjoy your technology section as I am quite into computer programming (on scratch.mit.edu), and my favourite issue was the one on 'The Science of Social Media', which was packed with facts.

I was recently reading in your magazine that cancer is the second highest cause of death in the world, which made me wonder: what is the first? And also, on a less mournful note, where do spiders get their thread to make their webs? I eagerly await your reply and the next issue!
Alissa Patterson, aged 11

Hi Alissa, thanks for your questions! The leading cause of death is cardiovascular disease, a group of disorders including coronary heart disease and stroke, which affect the heart and vessels. Globally, cardiovascular diseases cause around one in three deaths.

Regarding your second question, spider silk is really interesting — did you know it's stronger than any other natural or human-made thread? They use this versatile substance to build webs, to hang from, to catch prey, and even to use like a parachute.

The material is made from gel-like bits of protein produced in the spider's spinneret glands. As they are excreted they are hardened by acid to form the more solid fibre that make up spider webs. We hope that answers your questions and thanks again for writing to us.

Body clock hormones

Hello **HIW**,
Thank you for another interesting read this month! I was reading about our internal body clocks and I was wondering, if you have blackout curtains do you feel more tired in the mornings as melatonin hasn't stopped with morning light? Looking foward to the next read! Thank you!
Amy

Thank you for your email, Amy. You're right, melatonin is an important hormone that regulates our sleep cycles and its production is dependent on light. We rely on this hormone to fall asleep. During the day, light activates a part of your brain that tells the pineal gland to decrease production, but in the evenings, without light, melatonin production increases.

However, though it can be helpful to open your curtains as soon as you wake up to lower the amount of melatonin, another hormone called cortisol has a larger role to play in the process of waking up.

Cortisol acts like a wake-up signal as it dips before bedtime and increases throughout the night, peaking just before you wake up.

For now at least, human teleportation remains the stuff of science fiction

Happy birthday David!

Dear **HIW**,
I love your magazine and my favourite part is technology. I have a question about it too. Could we teleport, and if so how? I know it's to do with particles, atoms, electrons and things that everything is made of. It would make my birthday the best ever if you answered. Thank you.
Yours sincerely
David, age 11

Hi David
This is a really great question, and you're right, teleportation has everything to do with atoms and particles. Scientists are currently able to teleport single particles in laboratories. Recently, this was achieved by Chinese researchers who teleported photons (particles of light) from Earth to an orbiting satellite, the furthest distance achieved so far.

This is possible because of a strange property called quantum entanglement. When two quantum particles are formed simultaneously and at the same point in space they remain linked no matter how far apart they are moved. When one such particle is measured this influences the second, and scientists can use this to effectively change one particle into another — teleporting the information about the first particle to the second.

While this works at a quantum level, the idea of being able to teleport objects or even people is much more complex. While it may not be impossible — since our bodies are essentially just a huge collection of particles — it would be incredibly difficult to achieve.

Happy birthday David, from all of the team at How It Works!

What's happening on... social media?

Here's the latest from some of our favourite accounts...

"For the first time, scientists saw a gamma-ray burst caused by neutron stars colliding & saw the gravity wave"
@NASAGoddard

"We're proud to announce that New Scientist Live attracted 30,459 visitors. We're doing it all again next year! Save the date 20-23 September"
@newscilive

"I've made a film about being different, how it's sometimes difficult and sometimes brilliant, not just about what I can't do but what I can"
@ChrisGPackham

"I love being in the Sahara desert. I'm pleased it's come to visit me for a change. #RedSky #saharadust"
@dallascampbell

"FYI: A Cow can jump over the Moon if she aims where the Moon will be in three days, then leaps at about 25,000 miles per hour"
@neiltyson

"One of the coolest things to do in space? Watching Star Wars...half expected to see a Tie fighter out the Cupola! "
@astro_timpeake

HOW IT WORKS

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NEXT ISSUE

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STAR WARS SPECIAL

REVEALED: THE HYPOTHETICAL SCIENCE AND TECH THAT POWERS THE WEAPONS, VEHICLES AND DROIDS OF A GALAXY FAR, FAR AWAY...

From mice to blue whales, what makes us mammal?

How to save a life: discover the vital work of trauma teams

Find out how to build the ultimate robot

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FAST FACTS

Amazing trivia to blow your mind

QUEEN ELIZABETH II APPEARS ON COINS IN MORE THAN 35 DIFFERENT COUNTRIES

149.6MN KM
EARTH'S DISTANCE FROM THE SUN

1.24 BILLION
DENIM JEANS ARE SOLD WORLDWIDE EACH YEAR

FROM END-TO-END THE INTERNATIONAL SPACE STATION MEASURES

108.8 METRES

800
THE KNOWN NUMBER OF DINOSAUR SPECIES RECORDED TO DATE

THE DOMESDAY BOOK HAS A TOTAL OF

913
PAGES

MUMMIFYING THE DEAD BEGAN IN ANCIENT EGYPT CIRCA **3500BCE**

A POWERBALL CAN SPIN AT WELL OVER 20,000RPM, FASTER THAN AN F1 ENGINE

212.433KM THE WORLD RECORD FOR THE LONGEST CONTINUOUS JOURNEY BY A DRIVERLESS LORRY

ACROSS EUROPE

25,000
PEOPLE DIE EACH YEAR DUE TO INFECTIONS CAUSED BY ANTIBIOTIC-RESISTANT BACTERIA

THE WORD DUEL COMES FROM THE LATIN DUELLUM, MEANING 'A WAR BETWEEN TWO'

75%
OF CROP PLANTS REQUIRE ANIMAL POLLINATION

320,000KPH THE SPEED AT WHICH LIGHTNING STRIKES THE EARTH'S SURFACE

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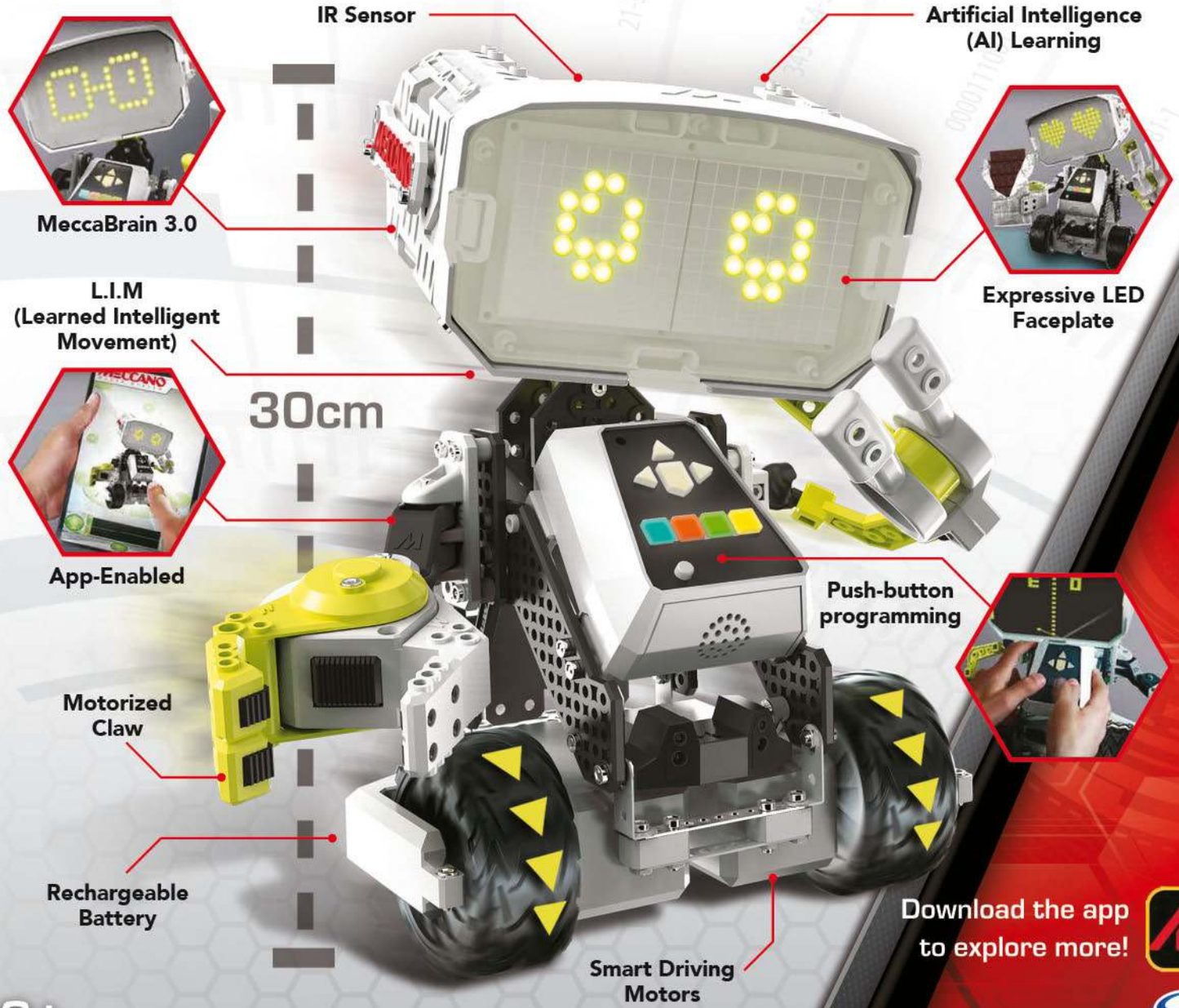

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